Popular Astronomy.

Vol. II. No. 8. APRIL, 1895. Whole No. 18.

THE STUDY OF PHYSICAL ASTRONOMY—SOME POINTS FOR BEGINNERS.

BY T. J. J. SEE.

FOR POPULAR ASTRONOMY.

In two preceding articles we have endeavored to point out the permanent scientific importance of physical astronomy, and to indicate the position which it ought to occupy in our universities and colleges. We have shown that physical astronomy is at the basis of astronomical science, and that as long as exact science shall exist the study of the laws and causes of the heavenly motions must continue to be the chief object of astronomical research. For it is evident that as physical astronomy alone enables us to foretell the exact positions of the bodies of the planetary system for observational purposes, it is also our only guide as to the absolute changes which the orbits undergo in the course of those immense ages which must elapse before the secular variations are completed. Thus knowing ultimately by researches in celestial mechanics the changes which the system will finally undergo from the action of universal gravitation, we ought eventually to be able to reverse our reasoning, and trace these bodies back to a remote state which will throw light upon the history of the solar system.

At the present time it is not enough to know the exact motions of the heavenly bodies and the changes which their orbits undergo in the course of centuries; we must also endeavor to investigate the development of the planets and satellites. The cosmogonic history of the heavenly bodies must be regarded as the ultimate problem of astronomy. And as man never can hope to see world-formation actually going on in the heavens, owing to the immense ages required for this process, he must rely chiefly on the results of physical astronomy to furnish the basis of a sound cosmogony. Thus while the theories of perturbations and of the tides throw light upon the action of central forces, and the changes which the orbits of revolving bodies undergo, the researches of mathematicians on the figures of equilibrium of rotating masses of fluid give us the means of investigating the process by which a nebulous mass breaks up into a system of bodies;

and therefore we are enabled to follow the great natural process by which the systems of the universe came to their present conditions. Although at present our knowledge of the processes of cosmogony is very limited, yet it seems probable that a beginning has been made in the right direction; and if physical astronomy shall be carefully prosecuted until the laws and causes of celestial phenomena are better known, there can be no doubt that cosmogony will sometime become a monument of the human mind even more sublime than physical astronomy, which has been justly regarded as the wonder and the admiration of the ages.

It is thus clear that both for practical work of observation and for the profound study of the planetary motions, physical astronomy will always be a necessity, whatever may be the progress in observational, photographic or instrumental development; and it is certain that the law of gravitation must continue to engage the attention of astronomers even at an epoch ten thousand years in the future. Some of the changes which the Earth's orbit undergoes cannot be precisely evaluated until a large part of certain great cycles has been completed, but in the mean time we get approximate values of the secular variations, and by extending our work over long periods we may hope that the exact motion of the Earth will finally be determined. Thus, Newton's discovery of the law of attraction transcends the ages and will continue to increase in importance as long as astronomy shall be cultivated as a science. For since we live upon the Earth, which is perturbed in its orbital and axial motion, it is clear that while civilization shall endure, and man shall have the capacity for science, he will desire to follow the motions of the heavenly bodies which will require a knowledge of physical astronomy. After the illustrious example of Galileo, Newton, Laplace, and their successors in physical science during the last three hundred years, it would be in the highest degree humiliating to the human mind if a race of degenerate astronomers should ever arise like the Arabians in the Middle Ages, who, from lack of energy and scientific vitality, would merely comment on the works of their predecessors, as the Arabians did on the work of Ptolemy and Hipparchus during the stationary period. We have no fear of this retrogradation, unless it shall result from political or social conditions which are beyond control: and even this could hardly happen in all the countries of the world at the same time. For whatever may be the advances of a practical or instrumental or mechanical character, and whatever may be the ease of certain branches of astronomical work, it is clear that scientific opinion in the future will rest on

the same principle which has guided it in the past, viz: that when any given piece of work or discovery is easy and requires small intellectual effort, it can not take a high rank in the annals of science. Only the really difficult discoveries can be assigned a lasting place in the history of astronomy; mind and intellectual effort will continue to triumph over matter and machines while the present healthy and natural instincts of the race endure.

We cannot close these contemplations without pointing out a fallacy which has obtained wide circulation. The claim has been made that the "new astronomy" is making the most rapid progress, and that the "old astronomy," while eminently respectable, is not making conspicuous advances at the present time. Such a claim is evidently fallacious in every respect, and it is difficult to understand how it could be advanced except by persons who fail to grasp the real nature and present condition of astronomical science. What greater advance has been made in our time than Hill's treatment of the motion of the Lunar Perigee, which has been one of the chief difficulties of mathematicians since Newton? How much greater progress than that just made by Chandler in his latitude work, which affects the positions of all the fixed stars used in fundamental astronomy, has been made in any other line? What greater progress could we hope for than is now being made by Newcomb in the formation of new tables for all the planets? If such work is being done in America it will readily be understood that the work of the late Professor Adams and of Darwin, of Tisserand and Callandreau, of Berberich and Gyldèn has not been less important.

So far from making small advances, it is probable that physical astronomy has made and is making the most rapid permanent progress of any branch of astronomical science, in spite of its difficulty and the small number of workers engaged in its development. Other branches of astronomy require much less intellectual effort, and hence have a great attraction for the majority; but what student of any worth desires to have an easy subject, when he could work on a higher and more difficult one?

Professor Young has reviewed the astronomical programme for 1895, in a paper reprinted in the March number of this journal; and after speaking of the principal celestial phenomena and the prospects of the building of the Yerkes Observatory of the University of Chicago, and of a large telescope at the Cape of Good Hope, he adds:

"And yet, after all, the real progress of astronomy depends more upon the unobtrusive, faithful, laborious work of the

mathematicians and routine observers than upon big telescopes and sensational discoveries."

This is of course the opinion of all thoughtful astronomers, and no reliable astronomers will enter upon a given line of work with a view of making discoveries of a sensational character. Some reputed discoveries are indeed sensational, but they seldom endure very long, or redound greatly to the credit of their authors. A student should therefore enter upon astronomical work with the hope of ultimate rather than immediate success, and with the assurance that no great work can rest on a narrow or inadequate foundation.

We have pointed out some of the lines of study which ought to be undertaken by those who desire to become proficient in physical astronomy. It remains to add a few words about the subject of astronomy in general, since it is important for the science of our country that every branch of it should be given adequate attention. There will be some students who do not take kindly to the mathematical side of astronomy, but who may have the taste and the energy to make excellent observers. We believe that in general lack of interest in mathematics arises from a bad beginning in that subject, which has developed to dislike, and is largely the fault of early instruction. It is a common experience of a student to lose interest in a difficult subject which he does not understand; but if the subject is clear he will find comfort and satisfaction in its pursuit. If therefore the student has good instruction and understands his subject, and yet has no interest in mathematical astronomy (the writer has however never met a student of this kind), it would be best for him to choose observational work and to adhere to it with steadfast perseverance. In this manner he may hope to render a good service to observational astronomy, and after all this work is of great importance; since the real progress of astronomy requires both the accumulation of observational material and the development of the analysis by which it is to be utilized. Thus, if Kepler had not discovered the laws of planetary motion as facts of observation, it is in the highest degree improbable that Newton could have discovered the law of universal gravitation. Without the observations of Flamsteed, Bradley and Tobias Mayer, Euler, Lagrange and Laplace might indeed have completed their theories of the general perturbations, but they could not have formed exact tables of the planets.

On the other hand, if the Greek geometer Apollonius of Perga had not composed a treatise on the conic sections which has de-

scended to our time, Kepler would have been ignorant of the properties of the ellipse and must have struggled in vain for the laws of planetary motion. And we may not hesitate to affirm that had not Laplace developed the theory of the perturbations of Uranus and induced Bouvard to reduce it to tables for the practical use of astronomers, the discovery of Neptune from the perturbations of Uranus, could not have been accomplished. Thus the discovery of Neptune depended especially on the work of Laplace and Bouvard, and without the services of either of these two great men, the one the profoundest of mathematical astronomers, the other his indefatigable computer, Neptune might still be an unknown body, and astronomy would have been deprived of the great services of Adams and Leverrier.

It must be remembered that astronomy is a science of nature, and therefore its progress depends on the joint development of mathematical analysis and of astronomical observation. The observer supplies the facts which the mathematician uses in his theories of the heavenly motions; and the neglect of either the analysis or the work of observation is fatal to astronomical progress.

In the United States at the present time there is danger of the neglect of mathematical theory, owing to its difficulty and the lack of sensationalism, and because defective teaching of late years has given rise to a strong tendency to jump into the current and swim with all the new fads that come along. Americans of sober judgment ought to remember that the principles of science are the same now as in the time of Newton and Laplace; and that the time will never come when the *Principia* and *Mécanique Céleste* will become obsolete. It is also perfectly clear that a sharp division between the "old" and the "new" astronomy is ill-advised, and mainly artificial, and the interests and principles of the two branches of the science are much the same.

Beginners and astronomers with limited appliances are sometimes discouraged by what is often represented as a fact, viz: that in order to accomplish any scientific work of importance in our time, a large expenditure of money and vast equipment is necessary. This certainly is not the case now any more than it has been in the past. The same claim was made by men of small capacity a hundred years ago, and has been repeatedly disproved by the great discoverers who have made modern astronomy. With vast equipment no great genius is required to obtain results of *some* importance, but to get the best possible results requires genius of a high order. On the other hand, many astronomers

with limited means have accomplished work of a monumental character; and what has happened in the past can easily happen again in the future. The absurd claim is made that because one Observatory spends $50,000 a year, another $40,000, and another $30,000; therefore no observatory can amount to much which has a smaller income. Such a claim is an insult to the intelligence of scientific men. While it is desirable that astronomers should have adequate support, so that they may devote their whole time and energy to their investigations, it cannot be maintained that wholesale squandering of money on reckless and ill-advised experiments and publications is conducive to the advancement of science. On this point, Dr. Chandler, in a recent address to the Boston Scientific Society, has well said: "Those institutions of the United States which can best develop real science, and properly educate and encourage the rising young astronomers of ability, have not the financial means to do so. Those institutions which have the means in abundance—I might say in wasteful abandance—have not the desire, or the noble broad mindedness which preceives the lamentable need, or the intellectual ability or qualification to meet it. Indeed, the presence of these extravagantly endowed institutions in a community operates not as an encouragement to the development of astronomy and astronomers, but as a blight. This carelessness as to the future of American astronomy seems to me more than selfish, it is criminal."

Our own country offers examples of what can be done by small means and genuine scientific enthusiasm. The epoch-making work of Professor Burnham in the discovery and micrometrical measurements of double stars, done in Chicago with a six inch telescope, must remain a perpetual inspiration to American astronomers. Professor Barnard's great work on comets was begun at Nashville with equally limited appliances, and was long prosecuted under very adverse conditions. To take an example further back in our history, Nathaniel Bowditch was a sailor boy at sea, and had no teacher of mathematics, and yet by his own exertions became the celebrated translator and commentator of Laplace's *Mécanique Céleste*, and thus the teacher of many illustrious men; while his disciple, Benjamin Peirce, was the teacher of many of our foremost living astronomers, and taken all around certainly one of the greatest mathematicians whom our country has yet produced. If Bowditch could do such work in the early part of this century, persons of our day ought not to despair, and to think that great telescopes and large sums of money are the only means of contributing to the advancement of American astronomy.

Students and beginners are sometimes discouraged by the obstacles to their progress, and by the humiliating custom of certain observatories by which all the work of subordinates is for some reason credited mainly to the director, or at least published under his name. This custom is so inconsistent with ordinary self-respect and with the high and exalted spirit of science itself, that it is very difficult to explain or justify on ethical grounds. Certainly we could not think of Newton, or Sir John Herschel or Struve condescending to such methods, and wherever this wholesale monopoly exists it must inspire distrust among the best class of scientific men and also tend to minimize the amount, and above all the *worth*, of the work of subordinates. Where such conditions exist, the only relief seems to be in other fields of labor, with *genuine scientific men*.

These the writer has always found, both in Europe and in America, sympathetic and honorable to the highest degree. It is remarkable that such selfish and shameful abuse of power should be a subject of complaint in the management of observatories and other scientific institutions in the Republic of the United States; but it unquestionably arises from the lack of scientific insight on the part of the public and the indifference of scientific men who ought to make known conduct which is really infamous. And although we may generally depend upon the justice of the judgment of history, yet it seldom happens that the evil which has resulted is entirely overcome.

The American student of astronomy, therefore, has some practical difficulties to contend with, but it is probable that they will diminish as time goes on; and Americans ought eventually to be able to establish among the workers of science a high and exalted spirit in searching for the truth, and according that generous recognition to meritorious work which is characteristic of the best scientific men and is demanded by the noble spirit of science itself.

THE UNIVERSITY OF CHICAGO, 1895, March 7th.

MARS.

PERCIVAL LOWELL.

OASES.

FOR POPULAR ASTRONOMY.

In the last paper I mentioned a certain feature of the canal system which is worth considerable attention—the striking propensity of the canals to rendezvous at several points.

If one were to draw lines at haphazard over the surface of a globe, he would find that although crossings of two lines would occur plentifully enough, crossings of more than two lines would occur practically never. Indeed if the lines were fine enough, multiple meetings could not take place at all, no matter how great the number of the lines. For the chance against any third line crossing two others at their point of intersection would be millions to one.

In the case of the Martian network, however, we are presented with a whole system of such improbabilities. Not only do we mark instances of more than two canals meeting at a point, but associability turns out to be the rule not the exception. An occurrence, therefore, a single instance of which would, in the event of lines drawn at haphazard, be one of the highest unlikelihood, happens habitually in the case of the lines on Mars. But haphazard is merely another word for lack of connecting cause. As, therefore, it is many millions to one against such a system being the result of chance, there must be a rational connecting cause under the observed physical connection. In other words that the canals should thus meet is somehow part and parcel of their very existence.

We may mark incidentally that this fact alone is fatal to the hypotheses that the lines are rivers or glaciation cracks, or even furrows ploughed by visitant meteorites. For in all these hypotheses the meeting points are not points in the argument. But as the meeting points are essential to the system, as we have just seen, and not haphazard irrelevancies, no theory about the canals can leave them out of account. Any theory that attempts to interpret the canals must *ipso facto* explain why they meet.

Now the most obvious explanation of such association that occurs to one who has not seen the canals, is that the canals are fissures radiating from centres of explosion or contraction. This idea as naturally commends itself to anyone before he has seen the canals, as unfortunately it does not commend itself after he has done so. For the lines on Mars bear no resemblance to a system of cracks of the sort; such, for example, as we see in the case of Tycho in the Moon. The look of the two systems is as unmistakably diverse as possible. Certainly no analogy whatever is suggested by the lines themselves; it takes a mind unbiassed by actual observation to conceive it. To mention but one point of dissimilarity since that is itself sufficient, the lines of Mars are strikingly of the same size throughout. This of course would be impossible under any process of bursting or shrinkage.

From what the lines cannot be, we may turn to what they possibly are. In the first place we may begin by saying that the lines do not go from the centres of the system but that they go to them. This statement has the merit of seeming utterly incapable of proof on the face of it. For the lines are stationary quantities, and do not move at all one way or the other. *E pur si muove* for all that.

A justification of the paradox introduces us to one of the most important outcomes of this year's observations—the oases.

The law regulating the rendezvousing of the canals at certain points finds its sanction in what turns out to be there. For it appears that there is something besides impalpable constrainment in the cause that thus attracts the canals toward one another. The meeting places are not simple junctions of the canals; there is something at the junction. This something shows itself as a round spot.

Scattered over the orange-ochre groundwork of the continental regions of the planet are any number of dark round spots. How many there may be it is not possible to state as the better the seeing the more of them there seem to be. I have mapped thirteen as existing on the single line of the Eosphoros, Eumenides and Orcus, including the Lake of the Sun and the Trivium Charontis, with a similar state of things elsewhere.

In spite, however, of their great number there is no instance of one occurring unconnected with a canal. What is more there is apparently none which does not lie at the junction of several canals. For though one or two as yet appear to be provided with but a single canal for connecting link with the rest of the dark areas, so many more have thus appeared at first and then later been found to have other canals running to them, that it seems more than probable that all are so circumstanced.

Reversely all the junctions appear to be provided with spots. In the case of the more difficult canals the spots are not evident. But inasmuch as the canals are easier to see than the spots such invisibility is to be expected; and in the case of crossings of the more conspicuous canals there is apparently no omission. Indeed to be spotless appears by its very nature to be an impossibility for a junction.

The spots, therefore, are part and parcel of the canal system. Secondly, they are terminal phenomena of the same.

Next in suggestiveness to the uniformity of their position, is their apparent uniformity of form. There is reason to believe that they are always round. For the better they are seen the more perfectly circular they look. In the worst seeing that ren-

ders them visible at all they show as irregular patches. As the seeing improves they contract into large round dots until under the best definition I have seen the most conspicuous among them, the Phoenix lake, quite startlingly circular, as if purposely so.

In size too they have a certain uniformity. Of those connected with the single canals, the largest are about 150 miles in diameter, the smallest about 70—the smallest that is yet seen. But the smaller are in the minority. Most of the spots are about 120 miles across, and bear a most suggestive family resemblance to one another.

When they are plotted upon a globe, they and their connecting canals make a most curious network over all the orange-ochre equatorial parts of the planet, a mass of lines and knots, the one marking being as omnipresent as the other. Indeed the spots are as peculiar and distinctive a feature of Mars as the canals themselves.

Premonitory systems of visibility, rather than views, of one of the spots, the Tithonius Lake may be seen in the best drawings made in the sixties, those by Lockyer, Kaiser and Dawes—the drawings of all three of these observers growing more and more admirable the closer they are studied. Several other spots have since been seen by Schiaparelli but it was not till 1892 at Arequipa that the spots were seen in anything like their true numbers. At Flagstaff this year I have been able to detect many more of them, to, I think, detection of their character.

The spots first became visible this year where they were especially prominent in 1892, in the region about the Solis Lacus. The Lake of the Sun, indeed, is surrounded by a cordon of canals beaded by spots. All the spots showed round with the exception of the Tithonius Lake which appeared oval, but in a drawing by Schaeberle made this year, two round spots take the place of the Tithonius Lake. This leads me to believe that the oblong look is due to quality and that the lake is therefore no exception to the rule; furthermore I have had a suspicion of two canals leading to it which hints at the same thing.

It was not, however, until later in the season when the Eumenides-Orcus began to show beaded that I first suspected the true character of the spot phenomenon. Suspicion indeed attaches to the very form of the spots. For, as we have seen, they are round. That is, they are convex not concave to the converging canals. Now were the spots natural enlargements of the canals at their termini, they should be star-shaped, that is concave to the canals. That they should on the contrary be convex seems inexplicable by any natural process of development.

We come now to the most suggestive feature about the spots: namely, that like the canals, they somehow grow. Like the canals they are not equally visible at all seasons. Indeed at certain seasons the rank and file of them are not visible at all; and this invisibility is not a matter of distance or obscuration but is intrinsic to the spot itself. Then just as the canals become evident so the spots gradually grow into recognition.

The history of the development is similar in both cases. Where the canals first make their appearance, there likewise are the first spots seen. The most southern spots, those nearest the south pole are evident early in the Martian season. At the end of last August, for example, the spots about the Lake of the Sun were perfectly visible; while at the same time those along the line of the Eumenides-Orcus were invisible; the same relation holding between the canals in the two parts of the planet. As the season advanced the more equatorial spots began to show, beading the Eumenides-Orcus, the great through line to the Trivium Charontis from the Solis Lacus region, the Pyriphlegethon running from the same region a more southerly course, and the perfect network of canals between the two. A good instance of the change that had occurred between the last of August and the early part of November is to be found in the relative intensities of the Phoenix Lake, the spot at the junction of the Iris and the Gigas and the spot where the Steropes (a newly discovered canal to the north of the Gigas) and the Nilus meet. In August the first was very conspicuous, the second only moderately so and the last barely discernible. By November the Phoenix Lake had become less striking, the upper Ceraunius spot relatively more so, and the lower one nearly as evident as the upper one had been.

This shows that the change is seasonal, but it also shows that the change sweeps gradually across the planet's face as a unit. For the lower Ceraunius spot lies in latitude 27° north. In other words the quickening is not local but depends in some wise upon the melting of the south polar snows.

Another important point about the spots is that their development is, apparently, not quite synchronous with that of the canals but follows it. One marks the canals first and the spots afterward and considering that the spots are much larger than the canals such priority in appearance might well be reversed. The spots are, therefore, in the first place seasonal phenomena, and in the second place phenomena that depend for their existence upon the prior existence of the canals.

A third feature in their development is that they grow not so much in area, apparently, as in depth of tint. The larger ones

especially seem to suffer no perceptible change in size from the time of their first appearance. They simply darken as time goes on.

Now when we put all these facts together, the presence of the spots at the junctions of the canals, their apparent invariability is size, their seasonal darkening, and last but not least the resemblance of the great equatorial regions of Mars to the deserts of our Earth, one solution instantly suggests itself of their character, to wit: that they are oases in the midst of that desert.

Here then we have an end and reason for the existence of canals and the most natural one conceivable—namely that the canals are constructed for the express purpose of fertilizing the oases. When we consider the amazing system of the canal lines we are carried to this conclusion as forthright as is the water itself; what we see being not the canal itself indeed but the vegetation along its banks, a theory propounded some years ago by Professor W. H. Pickering. Of course all such evidence of design may be purely fortuitous and with about the same probability, as it was put happily the other day, that a chance collection of numbers should take the form of the multiplication table.

But the shape of the spots hints at more. For there is no good reason in the course of nature why in such circumstance they should all apparently be round any more than they should all lie at the intersections of the canals. But there is good reason for both facts if the spots be cases of assisted nature If they be districts artificially fertilized by the canal system the larger would naturally be found at the intersections of the canals and intelligence would conduct to the circular form, in order to use the greatest amount of space for the least expenditure of exertion. For the circle is the figure that encloses the maximum area for the minimum average distance from its centre to any point situated within it. And such inference of design is in keeping with the curiously systematic arrangement of the canals themselves. Just as the canal takes the shortest distance from one point on the sphere to another, so the oasis encloses the greatest space at the least trouble. The whole system is trigonometric to a degree. If Dame Nature be at the bottom of it all she shows on Mars a genius for civil engineering quite foreign to the disregard for prosaic economy with which she is content to work on our own work-a-day world. Her love for elementary mathematics is evidently greater than is commonly supposed, a private passion which on tenantless Mars she is able to indulge unhampered by fear of unseemly ridicule.

March, 1895.

LAPLACE ON THE VARIATION OF THE LATITUDE.

BY ARTHUR B. HANCOCK

FOR POPULAR ASTRONOMY.

The subject of the variation of the latitude is one of such general interest that it may be well to quote some remarks of Laplace which bear on this subject. Dr. See in his lectures at this university has referred me to certain passages in the *Mécanique Céleste*; when translated from the French these may be of interest to the readers of POPULAR ASTRONOMY.

"We have demonstrated that the mean motion of rotation of the Earth is uniform on the supposition that this planet is entirely solid; and we have just seen that the fluidity of the sea and of the atmosphere cannot alter this result. The motions which the heat of the sun excites in the atmosphere and from which the trade winds arise might be supposed to decrease the rotation of the earth. These winds blow between the tropics from east to west and their continual action upon the sea, upon the continents and the mountains which they pass over might appear to diminish slightly the motion of rotation. But the principle of the conservation of areas shows that the total effect of the atmosphere on this movement must be insensible; for the solar heat expanding the air equally in every direction cannot alter the sum of the areas described by the radius vector of each molecule of the earth and of the atmosphere multiplied respectively by their corresponding particles; whence it follows that the motion of rotation is not altered. We are therefore assured that while the trade winds diminish this motion the other movements of the atmosphere which take place outside the tropics accelerate it by the same quantity. We may apply the same reasoning to earthquakes and in general to everything which can agitate the earth in its interior and on its surface. The displacement of its parts alone can alter this motion; if for example a body placed at the pole be transported to the equator, the sum of the areas remaining always the same, the motion of rotation of the earth would be slightly diminished. But in order that this may be sensible we must suppose great changes in the constitution of the earth."

(*Mécanique Céleste*, Tome II., Livre V. p. 365.)

"All astronomy rests upon the invariability of the axis of rotation of the Earth at the surface of the terrestrial spheroid and upon the uniformity of this rotation. The duration of a revolu-

tion of the Earth about its axis is the standard of time; it is therefore very important to appreciate all the causes which might alter this element. The terrestrial axis moves around the pole of the ecliptic; but, since the epoch when the application of the telescope to astronomical instruments has given the means of observing terrestrial latitudes with precision, no variation in these latitudes has been recognized which could not be attributed to errors of observation; which proves that the axis of rotation has since this epoch corresponded very nearly to the same point of the terrestrial surface; it appears then that this axis is invariable. The existence of similar axes in solid bodies has been known for a long time. We know that each of these bodies has three principal rectangular axes, around which it can turn uniformly, the axis of rotation remaining invariable. But is this remarkable property common to bodies which, like the Earth, are covered in part by fluid? The condition of equilibrium of the fluid accordingly adjusts itself to the conditions of the principal axes; it changes the figure of the surface when there is a change of the axis of rotation. The question, therefore, arises whether among all the possible changes there is one in which the axis of rotation and the equilibrium of the fluid are invariable. To this end I have proved that if we pass a fixed axis very near to the centre of gravity of the terrestrial spheroid around which it may turn freely, the sea may always assume upon the surface of the spheroid a constant state of equilibrium. I give, for the determination of this state, a method of approximation arranged according to the powers of the ratio of the density of the sea to the mean density of the Earth; a ratio, which being less than one-fifth, renders the approximation convergent. The irregularity of the depth of the sea and of its contour does not permit us to obtain this approximation. But it suffices to know its possibility, to be assured of the existence of a state of equilibrium of the sea. The position of the the fixed axis of rotation being arbitrary, it is natural to suppose that among all the changes it might undergo in this position there is one in which the axis passes by the common centre of gravity of the sea and the spheroid which it covers, in such a manner that, this fluid being in equilibrium and congealed in this state, this axis would be a principal axis of rotation of the terrestrial spheroid and the sea combined; it is evident that on giving to the congealed mass its fluidity the axis will always be an invariable axis of the entire Earth. I have proved by analysis that such an axis is always possible, and I give the equations which determine its position. On applying these equations to

the case where the sea covers the entire spheroid I am led to this theorem:

If we imagine the density of each layer of the terrestrial spheroid diminished by the density of the sea, and if, by the centre of gravity of this imaginary spheroid we conceive a principle axis of rotation of this spheroid, on making the earth turn around the axis, the sea being in equilibrium, this axis will be the principal axis of the entire earth whose centre of gravity will be that of the imaginary spheroid.

Thus the sea which covers in part the terrestrial spheroid not only does not render impossible the existence of a principal axis, but, by its mobility and by the resistance which its oscillations encounter, it gives to the earth a permanent state of equilibrium if any causes whatever shall trouble it.

If the sea were sufficiently deep to cover the surface of the terrestrial spheroid, on supposing it to turn successively around the three principal axes of the imaginary spheroid of which we have just spoken, each of these axes would be a principal axis of the entire earth. But the stability of the axis of rotation takes place, as in a solid body, only relative to the two principal axes for which the moment of inertia is a maximum or a minimum. There is however between a solid body and the earth this difference, viz: that in changing the axis of rotation of the solid body the figure does not change, while on the other hand by this change the surface of the sea takes another figure. The three figures which this surface takes in turning successively with the same angular velocity of rotation around each of the three axes of rotation of the imaginary spheroid have very simple relations, which I determine, and it follows from my analysis that the mean radius among the radii of the three surfaces of the sea, corresponding to the same point of the surface of the terrestial spheroid, is equal to the radius of the surface of the sea in equilibrium upon this spheroid deprived of all rotatory motion.

I have discussed in book V the influence of internal causes, such as volcanoes, earthquakes, winds, the currents of the sea, etc., upon the duration of the rotation of the earth, and I have proved, by means of the principle of areas, that this influence is insensible, and that to produce a sensible effect, it would be necessary in virtue of these causes that considerable masses be transported to great distances, which has not taken place during historical time. But there exists an interior cause of alteration of the duration of the day which has not yet been considered, and which viewed from the importance of this element deserves a

special discussion. This cause is the heat of the terrestial spheroid. If, as everything leads us to believe, the entire earth was originally fluid, its dimensions have necessarily diminished with its temperature, its angular velocity of rotation has gradually augmented and it will continue to increase until the earth comes to the constant state of mean temperature of the space in which it moves."

Laplace here shows that the duration of the day has not changed by $\frac{1}{100}$ of a second since the time of Hipparchus.

(*Mécanique Céleste*, Tome V, Livre XI. p. 22-24.)

"We find by means of pendulum experiments that the oblateness of the terrestrial sphereoid is $\frac{1}{310}$. The small difference of this oblateness from those which the measures of the terrestrial degrees and the lunar inequalities give, proves that the surface of this spheroid would be very nearly one of equilibrium if it should become fluid. From this and from the circumstances that the sea leaves uncovered vast continents we conclude that it ought to be shallow, and that its mean depth is of the same order as the mean height of the continents and the islands above its surface, a height which does not surpass 1,000 metres. This depth is then a small fraction of the excess of the radius of the equator above that of the pole, an excess which surpasses 20,000 metres. But just as high mountains cover certain portions of the continents, in the same manner there may be great cavities in the bottom of the sea. However it is natural to suppose that their depth is less than the elevation of the high mountains, since the deposits of rivers and dead bodies of marine animals, carried by the currents, would tend in time to fill up these cavities.

This result is important for natural history and geology. One cannot doubt but that the sea has covered a great part of our continents, upon which it has left incontestable traces of its sojourn. Moreover the successive effacements of the islands and of a part of the continents followed by extensive effacements of the basin of the sea which have covered the parts previously submerged, appear to be indicated by diverse phenomena which the surface and the strata of the actual continents present to us. To explain these effacements it suffices to attribute more energy to causes like those which have produced the effacements recorded in history. The effacement of a part of the basin of the sea uncovers another part of the land which is the more extensive in proportion as the sea is less deep. Thus vast continents have been able to rise from the ocean without great changes in the terrestrial spheroid. The property which this figure enjoys, of

differing but little from that which its surface would take in becoming fluid, requires that the lowering of the level of the sea has been but a small fraction of the difference of the two axes of the pole and of the equator.

Every hypothesis founded on a considerable displacement of the poles at the surface of the Earth ought to be rejected, as incompatible with the property of which I shall now speak. Some have imagined this displacement in order to explain the existence of elephants whose fossil bones have been found in such great abundance in the climates of the north, where the real elephants could not live. But an elephant which has been supposed with probability contemporary with the last catastrophe, and which has been found in a mass of ice, with its body well preserved, and whose skin was covered with a great quantity of hair, has proved that this species of elephant was protected by this means from the cold of the northern climate, in which it could live and even flourish. The discovery of this animal has therefore confirmed what the mathematical theory of the Earth makes known, namely, that in the revolutions which have changed the surface of the Earth and destroyed many species of animals and plants, the figure of the terrestrial spheroid and the position of its axis of rotation at its surface have undergone but small variations."

(*Mécanique Céleste*, Tome V, Livre XI, p. 19-20).

THE UNIVERSITY OF CHICAGO,
1895, March 4th.

THE PHOTOGRAPHY OF COMETS WITH NOTES CONCERNING COMET RORDAME.

W. J. HUSSEY.

I.

FOR POPULAR ASTRONOMY.

The photography of comets is not among the newest things of astronomy. Nearly fourteen years have passed since Dr. Draper, of New York, and M. Janssen, of Paris, succeeded in obtaining permanent records of the changing forms of the bright comet discovered in 1881 by Mr. Tebbut, Comet 1881 III. The previous attempts to photograph comets had been unsuccessful and it was accordingly no small triumph when Dr. Draper obtained a photograph of this comet which showed not only its head but also about ten degrees of its tail. The photographic plates then

in use were very slow in comparison with those which are now used for this kind of work, and consequently very long exposures were required in order to secure even very moderate results. His first photograph was obtained on the evening of June 24, 1881, the exposure was seventeen minutes, a longer exposure being prevented by clouds coming on. This photograph showed the head of the comet, and only a very little of the tail. On another night an exposure of one hundred and sixty-two minutes gave the photograph referred to above. M. Janssen was somewhat less successful than Dr. Draper for his photographs show the head of the comet and only two degrees of its tail. The comet was so bright and was photographed so readily that Dr. Draper at once concluded that it might be possible to photograph its spectrum, and his conclusion was justified by the results he soon obtained. But in this he had been anticipated. On the same night that he had obtained his first photograph of the comet, Dr. Huggins, in England, had obtained a photograph of its spectrum, the first comet spectrum to be recorded in this way.

In the following year, 1882, the great comet appeared in September and remained under observation until the following June. It was, unquestionably, "the most magnificent celestial spectacle which has been presented to us for a quarter of a century; for not since the great comet of Donati, in 1858, has so splendid an object appeared." Magnificent as it was it did not receive from photographers the attention it deserved. This is not especially surprising for astronomical photography was then in its infancy. If such a comet were to appear now it would be photographed hundreds and perhaps thousands of times and the photographs obtained would certainly afford more accurate data for the study of cometary phenomena than has been obtained visually from all the comets of the past. It would be photographed by amateurs with ordinary cameras strapped to whatever telescope mounting happened to be available, or even to such mountings as they might improvise, more successfully, perhaps, than was the case with the great comet of 1882. This comet was photographed at the Royal Observatory at the Cape of Good Hope by means of a large portrait lens. The results sufficiently demonstrated the efficiency of such lenses for this kind of astronomical work. Their short focal length and relatively great light power render them especially suitable for photographing objects having large angular dimensions, such as comets, nebulæ and the Milky Way.

From 1883 to 1891 very few photographs of comets were taken and even those which were obtained did not add much to

our knowledge of the phenomena exhibited by these bodies. Nevertheless this was a period of great progress in astronomical photography. The modern dry plate was improved and brought to a high degree of perfection; telescopes designed especially for photography were constructed and other telescopes were remodelled so as to enable them to do this kind of work. Towards the end of this period all that was wanting was comets of sufficient size and brightness upon which to work. When the first comet of this class came (April, 1892) the improved photographic plate demonstrated its superiority to the eye in dealing with questions relating to structure and changes of form. It could grasp what the eye could not see. It could picture the comet in all its detail more skillfully and more accurately than any artist. In short, its testimony had the elements, completeness, permanency and accuracy.

During the past three years several comets have appeared, but none of them have been bright enough to be classed among the great comets. Five of them, however, have been sufficiently conspicuous to afford especially interesting photographs. These were the comets discovered in 1892 by Swift and Holmes, those in 1893 by Rordame and Brooks, and that in 1894 by Gale. In what follows it is my purpose to call attention to some of the principal phenomena exhibited by the photographs of these comets. In particular I shall refer to my series of photographs of Comet Rordame. This series comprises thirteen photographs, six of which are very good. Two were made with a small camera having a lens (Beck, rectilinear, $6\frac{1}{2} \times 8\frac{1}{2}$) about an inch and a quarter in diameter. The remaining eleven were made with the Crocker telescope, (Willard lens), of the Lick Observatory. Of these three were short exposures of from six to eight minutes, taken to obtain an idea of the photographic intensity of the comet's light; one an exposure of twenty minutes; one a comet trail, made after the exposure of twenty minutes, when the comet was so near the horizon that it could not be seen in the finder used for guiding; and the remaining six were exposures of an hour and upwards. The photographs were taken on six evenings, 1893, July 11 to 18 inclusive, except July 17. The plates used were the most sensitive obtainable, being about twice as rapid as Seed 26 X.

Visual observations have shown that comets often undergo rapid and very complete changes of form. Such changes have been observed in both large and small comets. As a notable example in the case of a small one may be mentioned the changes of

form, size and brilliancy of Holmes' comet. When discovered, Nov. 6, 1892, it was perfectly round with a very definite outline. Although receding from the Earth and the Sun it increased in apparent size until its diameter was about five times as great as at discovery, and at the same time its brightness decreased out of all proportion to the law of inverse squares. Its outline became hazy and indistinct, and a short tail appeared. On January 14th it was very faint; two days later it had changed into a bright, hazy, star-like object, having a diameter only one-tenth as great as at the time of discovery. For the next four days it remained about the same size, but decreased somewhat in brightness. It then increased in size and again became fainter.

The changes which have been observed visually do not in any case compare with those which have been demonstrated by photography. There were radical differences of form in Rordame's comet on each evening that I photographed it. Professor Barnard's photographs of various comets, notably Swift's and Brooks', show similar differences. The fact stands forth prominently that these comets were continually undergoing rapid and almost complete transformations of form. It appears probable that this is the case with all comets, both large and small, and that the principal reason that it has not been observed lies in the fact that the conditions of observation were not sufficiently favorable. At any rate it appears safe to say that the comets which behave in a quiet and orderly manner are exceptional. They are the ones which are remarkable, remarkable because they are not continually doing something unexpected. Comets are generally doing something unexpected; we may perhaps come to regard their actions in a converse manner and not be surprised at anything which they may do.

The nucleus may be sharply defined and starlike, or ill-defined or even indistinguishable from the coma surrounding it, the coma may change in shape, and size and density; envelopes may be thrown off sometimes singly, sometimes in complex systems; the tail may consist of a single streamer (at least apparently so) or of an indefinite number of them; the streamers composing the tail may leave the coma in a single compressed bundle or they may spring from it in widely divergent and loosely connected groups; they may be smooth and straight and distinct, or they may be lumpy, crooked, interlacing and spirally twisted; or again, they may be broken into fragments and scattered as though they were as smoke and driven by a wind. The appearance one day affords no indication as to what it may be the next. Conditions and ap-

pearances seem to change incessantly. The most radical changes of form have been observed in almost every reasonably bright comet that has been photographed. The changes are sometimes so rapid that they become conspicuous in an hour or two. The changes observed in the tail of Comet Rordame and the important inferences to be drawn from them will furnish material for a subsequent article, the remainder of this one will be devoted to a consideration of the head of this comet.

The Coma.—The coma of Rordame's comet was decidedly elliptical in outline during the entire period covered by the photographs, 1893, July 11 to 18 inclusive. The minor axis coincided with a line drawn towards the sun, or, at least, nearly in this direction. The density of the coma, judging from the photographs and also from the appearance in the finder increased from day to day and at first without any considerable change in its dimensions. In the last photograph taken, however, the coma is very much smaller than in the preceding ones and the change is very much greater than can be attributed to the slightly increased distance of the comet. The Moon was then about five and a half days old and consequently produced a strong illumination of the sky which no doubt extinguished the fainter portions of the outer coma. But even allowing for this the change in apparent size is so great that it must be regarded as a real change, similar, perhaps, to the changes which took place in Holmes' comet, mentioned above. Similar changes have also been observed in other comets. In the case of Gale's comet, Mr. Russell, of the Sydney Observatory, carefully estimated the diameter of the head on at least fourteen nights and found that it varied irregularly, all the way from two to twenty-three minutes of arc. In comparison with this the changes in the dimensions of the coma of Rordame's comet were slight.

Extension to the Coma.—In all the photographs there is a short and very faint extension to the coma in the position which would be occupied by a tail of the third type, according to Bredichin's theory. According to this theory the tails of this type consist of heavy materials which are driven from the comet by its own and the Sun's repulsive forces. Bredichin's investigations have led him to suppose that tails of this type may consist largely of iron vapor accompanied, perhaps, by other materials having nearly the same atomic weights. Tails of this type are of rare occurrence, at least as far as records go, and on this account this slight extension possesses more than usual interest. No streamers, such as compose the tail proper, are observable in it.

But its shortness and especially the effects which are produced by rapid motions, to be considered in another article, will probably satisfactorily account for their absence. The presence of iron vapor in this comet was not detected by the spectroscopic observations. This, as far as it goes, is an item of negative testimony to the effect that this extension is not a miniature tail of the third type, or that Bredichin's supposition as to the character of the material composing this type of tails is incorrect. But it may be that the radiations from the material composing this extension were too feeble to be perceptible in the spectroscopic observations.

The Nucleus.—In some of the photographs, especially in some of the earlier ones, the nucleus is bright and distinct. It also appeared so in the finder. In the later photographs it can not be easily made out. It naturally became obscured when the coma increased in brightness. In all cases, however, its position can be easily determined by looking at the back of the plates, with reflected light. It then appears sharply defined and star-like.

LELAND STANFORD, JR., UNIVERSITY,
Palo Alto, California.

ALMANACS.

R. W. McFARLAND.

II.

FOR POPULAR ASTRONOMY.

In the further elucidation of the general subject now under consideration, it may be well to say that the idea of celestial influence on mankind, runs through the literature of all ages and all nations that have a literature. It would be easy to quote from the classical writers of antiquity to prove the assertion, but they will be passed over.

It is all based on a wide-spread belief that both animal and vegetable life was continuously dominated by the heavenly bodies.

In a very old book which most of my readers have seen, we read, "Let there be lights in the firmament of the heaven, to divide the day from the night, and let them be for *signs*, and for seasons, and for days, and years." The liberty of underscoring one word has been taken, the more readily to draw attention to that word. The human mind is naturally superstitious, and the foundation of a large superstructure is laid in that one word

above referred to. How far it has been efficacious as a fountain of belief, I do not undertake to say. Nor will I attempt to show how far this natural disposition has been cultivated by designing priests of the various religions found among men. There is little doubt, however, that such influence has been very great.

An early example of the supposed intimate connection between things terrestrial and things celestial, is the story of the standing still of the Sun and Moon, in the 10th Chapter of Joshua. "And the Sun stood still, and the Moon stayed, until the people had avenged themselves upon their enemies." [It is not stated how the enemy considered it.] But a more direct intermingling of these bodies is found in the Song of Deborah and Barak, in the 5th Chapter of Judges. "They fought from heaven; the stars in their courses fought against Sisera."

Throughout all the later history of the Jews and of the nations with which they were most closely associated, the *astrologer* was always in demand. He may be called a *constant quantity*. Isaiah, Chapter 47 : v. 13; "Let now the astrologers, the star-gazers, the monthly prognosticators, stand up and save thee from these things that shall come upon thee."

Also, in Daniel, Chapter 5 : v. 7; "The king cried aloud to bring in the astrologers . . .", and so on through the ages.

Another case in point is the use Columbus is said to have made of an eclipse of the Moon, in order to replenish his commissary department.

In very early life I heard elderly people speak of the comet of 1811, as having been a precursor of the war between Great Britain and the United States. In 1862 when with others I was in the army in Virginia, it was stated to me by many different persons that the comet of 1861 was a certain harbinger of the war then in this country. Of course we saw both the comet and the war;—the difficulty in this case was to join the two as cause and effect.

Inasmuch as I purpose to show that the language of astrology is embodied in our every day almanacs in various ways, it may not be irrelevant or inappropriate to give a few quotations from our two great English writers, Shakespeare and Milton. Both of them continually bring in expressions showing the hold which astrological belief had on the people at large,—that it is interwoven in all life's thousand sides,—that it is a perpetual fountain for both high and low alike. The latter in his Paradise Lost has embodied not only the whole body of astrological belief, but also the philosophy of nature, and the mythology of many nations.

The terms, *hot*, *cold*, *moist*, and *dry* are household words to the astrologer. In Book 2, Paradise Lost, we find:

> . . . . . Where eldest Night,
> And Chaos, ancestors of Nature, hold
> Eternal anarchy, amidst the noise
> Of endless wars, and by confusion stand.
> For hot, cold, moist, and dry, four champions fierce
> Strive here for mastery."

In the same book is another passage often quoted:

> . . . . . "Satan stood
> . . . and like a comet burned,
> That fires the length of Ophiuchus huge
> In th' artic sky, and from his horrid hair
> Shakes pestilence and war."

In Book Fourth,

> . . . . . "For proof look up
> And read thy lot in yon celestial sign."

Again, in Book First:

> "The sun new ris'n
> . . or from behind the moon,
> In dim eclipse, disastrous twilight sheds
> On half the nations, and with fear of change
> Perplexes monarchs."

The word *disastrous* embodies the same idea of bad influence from the stars. Almost everybody is familiar with the description of the witches' cauldron, in Shakespeare's Macbeth:

> . . . . . "Slips of yew
> Sliver'd in the moon's eclipse."

Again in Richard II:

> "'Tis thought the king is dead: we will not stay—
> The bay trees in our country are all wither'd,
> And meteors fright the fix'd stars of heaven;
> The pale-fac'd moon looks bloody on the earth,
> And lean-look'd prophets whisper fearful change:
> * * * * * * * * * * * *
> These signs forerun the death or fall of kings."

Let the reader remember that the sole object of Astrology was to foretell events affecting the human race, and especially of kings and others in authority, and that Astronomy for centuries was but the servant of Astrology. The latter science—so-called—had assigned to the Sun, the Moon, the planets, to some of the stars, and to the signs of the Zodiac, certain influences over men and things; and that the four elements,—Earth, air, fire, and water, always joined hands (so to speak) with the heavenly bodies. In this way influences whether good or evil were intensified or lessened, as the case might be. Most of the signs used in the alma-

nacs of to-day, come to us from antiquity, or were invented by the astrologers. The ordinary signs of the Zodiac differ but slightly from the figures in the Egyptian zodiac of a thousand years before Christ.

The part of the body supposed to be specially influenced by planetary action, is shown at this day in many almanacs, and was formerly given in all. It is the human figure, "with sticks pointing at it all around,"—the word Aries and the sign for the same being over the head, and other figures and signs for the neck, the shoulders, the breast, etc. All people are familiar with the figure.

When two of the heavenly bodies came to the meridian at the same hour, they were said to be in conjunction, and this sign, ☌, is a sort of short way of saying "conjunction." When bodies reach the meridian twelve hours apart, they are in "opposition," and this ☍ is the sign. If the bodies are six hours apart, they are said to be in "quadrature," or "square," and the corresponding sign is □. When they are separated by a third part of the heavens, they are in "trine," and the sign is this, △: finally, when separated by one sixth part of the heavens they are in "sextile," and the sign is a six-rayed star, ✶.

These signs together with the characters for the planets, constitute a sort of algebraic language, very brief, very compact, and very easily read. Here are the principal ones; ☉, the Sun; ☽, the Moon; ☿, Mercury; ♀, Venus; ♂, Mars; ♃, Jupiter; ♄ Saturn. These are the characters to "conjure with," but only in connection with the various good or bad influences which the planets and the stars were capable of producing. These supposed influences depended greatly or wholly on the part of the heavens in which the planets might be situated at any given time. Milton has all this beautifully summed up in the following passage from Book Tenth, with which quotation we will bid the poets adieu:

* * * * "The Sun
Had first his precept so to move, so shine,
As might affect the earth with cold and heat
Scarce tolerable, and from the north to call
Decrepit winter; from the south to bring
Solstitial summer's heat. To the blank moon
Her office they prescribed. To the other five
Their planetary motions and aspects,
In sextile, square, and trine, and opposite
Of noxious efficacy, and when to join
In synod unbenign; and taught the fix'd
Their influence malignant when to shower,—
Which of them rising with the sun, or falling,
Should prove tempestuous."

ON THE VARIABLE STARS OF SHORT PERIOD.

PAUL S. YENDELL.

IV.

The Sagittarius Group.

For Popular Astronomy.

The four stars with which I close this series of papers form a group which is in several respects rather remarkable. They are all in a space of twelve degrees square, between R. A. $17^h\ 40^m$ and $18^h\ 26^m$ and between Decl. $-29°\ 35'$ and $-18°\ 54'$. Their periods of variation are from $5^d.8$ to $7^d.6$. And the variability of three of the four was discovered by one man, Schmidt, who was one of the most persistent and indefatigable observers that ever worked upon variable stars. All four are distinctly of the η Aquilæ type of variables.

They are all bright stars and all but U can be observed with the field glass. W and X are, for good reasons, decidedly difficult stars, and the beginner will find them discouraging if he attempts them at first. Y is more satisfactory, and U will also be found interesting if proper optical aid is used, though its strong orange color may be troublesome.

The comparison-stars, light-scales and the mean light-curves given in this paper are all those used by myself. The general chart is from Schurig's Atlas, and the small chart of U Sagittarii is from Schönfeld's Southern Durchmusterung.

I would here call attention to an omission in the third paper in this series published in the February number. The fourth line from the foot of p. 272 should read, "The comparison-star *a* appears," etc.

6368 X Sagittarii.

R. A. $17^h\ 41^m\ 16^s$ Decl. $-27°\ 47'.6$ (1900).

Elements of Variation.

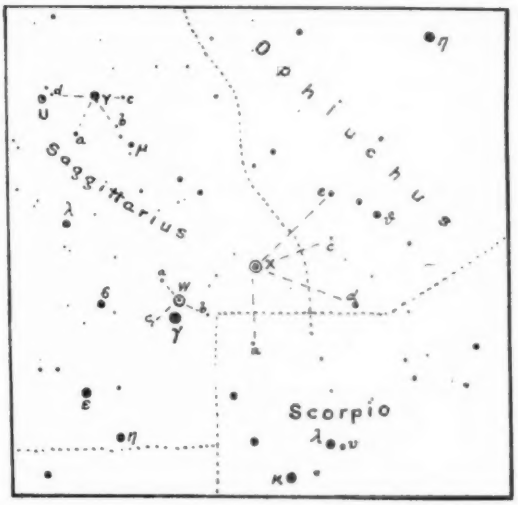
Greenwich M. T.

Maximum, 1870 August 16.78 + $7^d.01185$ E.

Minimum precedes maximum $2^d.876$.

The variability of this star was discovered by Schmidt in 1866. It was assiduously observed by him and by others up to the present time.

The variations are marked, but difficult to follow in this latitude on account of the star's low southern declination.



My comparison-stars, light-scale and mean light-curve are as follows:

COMPARISON-STARS.

POSITIONS, 1875.

		h	m	s		°	′	Mag.	Lt.(steps)
d = d 45 Ophiuchi	R. A.	17	19	22	Decl.	− 29	45.0	4.6	10.4
c = 51 Ophiuchi		17	23	47		− 23	51.8	5.2	5.7
e = 151 (U. A.) Ophiuchi		17	23	59		− 26	10.3	6.2	0.0

MEAN LIGHT-CURVE.

d.	st.	d.	st.	d.	st.	d.	st.
− 2.74	2.40	− 0.50	8.00	+ 1.00	7.45	+ 3.00	3.85
2.50	2.60	− 0.30	8.50	1.50	7.35	3.50	3.30
2.00	3.75	0.00	8.97	2.00	7.13	4.00	2.70
1.50	5.20	+ 0.50	8.06	+ 2.50	6.42	+ 4.27	2.40
− 1.00	6.60						

6472 W SAGITTARII.

R. A. $17^h\ 58^m\ 38^s$ Decl. − 29° 35′.1 (1900).

ELEMENTS OF VARIATION.

GREENWICH M. T.

Maximum, 1866 September 4.45 + 7*d*.5946 E.

Minimum precedes maximum 3*d*.00.

The variability of W Sagittarii was discovered by Schmidt in 1866. He observed this star, as well as X and U Sagittarii, very continuously for a number of years, accumulating a large amount of data. I have observed it as regularly as practicable since 1888.

The beginner will find this star difficult, as its situation with regard to its principal comparison-stars is such as to render very careful observation necessary in order to get rid of the disturbance of the estimates from this cause.

The comparison-stars, light-scale and mean light-curve are as follows:

COMPARISON-STARS.

POSITIONS, 1875.

			h	m	s		°	′	Mag.	Lt.(steps)
a = 31 (U. A.)	Sagittarii	R. A.	18	0	10	Decl.	− 28	28.2	5.1	7.4
b = 14	"	"	17	51	4		− 30	14.3	5.4	2.7
c = 37	"	"	18	2	2		− 30	44.8	5.9	0.0

MEAN LIGHT-CURVE.

d.	st.	d.	st.	d.	st.
− 3.00	4.55	− 0.50	9.34	+ 2.00	6.65
2.50	4.80	0.00	9.55	2.50	6.44
2.00	5.40	+ 0.50	9.07	3.00	6.25
− 1.50	7.15	1.00	8.00	3.50	5.57
− 1.00	8.67	+ 1.50	7.10	+ 4.00	4.50

6573 Y SAGITTARII.

R. A. $18^h\ 15^m\ 30^s$ Decl. − 18° 54′.3 (1900)

ELEMENTS OF VARIATION.

GREENWICH M. T.

Maximum, 1886 September 25.02 + 5*d*.7732 E.

Minimum precedes maximum 1*d*.90.

This variable was discovered in 1886 by Sawyer, in the course of his verifications of the Uranometria Argentina magnitudes. It has been under observation by its discoverer and myself pretty constantly since its discovery.

It is fairly easy of observation, and is recommended to the amateur as an object that will repay watching.

The comparison-stars, light-scale and mean light-curve are as follows:

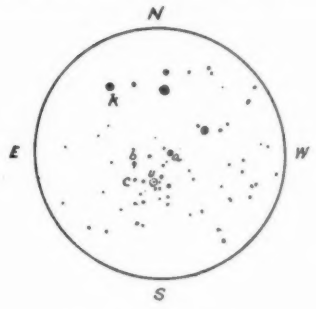
COMPARISON-STARS.

POSITIONS, 1875.

			h	m	s		°	′	Mag.	Lt.(steps)
a = 21	Sagittarii	R. A.	18	17	54	Decl.	− 20	36.3	5.1	16.0
b = 43 (U.A.)	"		18	7	46		− 20	45.8	5.8	10.2
c = 45	"	"	18	8	10		− 18	41.9	6.3	5.8
d = 74	"	"	18	22	51		− 18	48.3	6.2	2.9

MEAN LIGHT-CURVE.

d.	st.	d.	st.	d.	st.	d.	st.
− 1.90	5.98	0.00	12.10	+ 1.50	9.25	+ 3.00	6.80
1.50	6.40	+ 0.50	11.50	2.00	8.30	3.50	6.25
1.00	8.75	+ 1.00	10.35	+ 2.50	7.50	+ 3.75	6.05
− 0.50	11.30						



6636 U SAGITTARII.

R. A. $18^h\ 26^m\ 0^s$ Decl. $-19°\ 11'.7$ (1900).

ELEMENTS OF VARIATION.

GREENWICH M. T.

Maximum, 1870 July $1.0 + 6^d.7446$ E.

Minimum precedes maximum $2^d.48$.

This is one of Schmidt's stars. Since him I am, so far as I know, its only observer.

It is a very interesting star to watch, as its changes are very regular, and the comparison-stars convenient.

A small telescope is necessary for observing this star as it needs a power of at least ten, to separate it from the small cluster of which it is the central star. It is of a full orange color, and estimates should be made with deliberation, as its color affects the retina slowly, and a hasty estimate is likely to give too low a value.

The small chart given above is from the Durchmusterung, and is supposed to represent the region under a magnification of ten times.

In the list of comparison-stars, the D. M. numbers and positions are omitted, as they are all in the same low-power field with the variable, and readily identified by their relative positions. The magnitudes are Schönfeld's:

COMPARISON-STARS.

	Mag.	Light (steps).
k	7.1	15.9
a	7.5	10.0
b	8.0	5.1
c	8.5	0.0

MEAN LIGHT CURVE.

d.	st.	d.	st.	d.	st.
− 2.48	1.63	0.00	11.80	+ 2.50	3.30
2.00	1.80	+ 0.50	8.80	3.00	2.65
1.50	3.30	1.00	6.28	3.50	2.10
1.00	5.75	1.50	5.00	4.00	1.72
− 0.50	9.40	+ 2.00	4.08	+ 4.26	1.63

During the summer of 1894, two new stars have been added to this class, Y Aquilæ and *d* Serpentis, respectively by Dr. Chandler and myself.

Neither of them, however, is a fit subject for a beginner, and the former is exceedingly difficult to observe, its range being about the least so far certainly known among this class of objects. W Cephei is not included in these papers, as being altogether too difficult to be dealt with by any inexperienced observer; and one of our best and most experienced men in this class of work has not yet been able to confirm it, though from private information from other quarters its variability appears certain.

Nearly or quite all of the stars which have been taken up in these papers are now observable, either in the evening (ζ Geminorum, T Monocerotis, δ Cephei) or in the morning (δ Cephei, X Cygni, T Vulpeculæ, S Sagittæ, η and U Aquilæ, β Lyræ, the Sagittarius Group), and their observation requires so little time and apparatus, that it is hoped that some of our interested readers may be induced to take up observation of one or more of them.

DORCHESTER, Mass., 1895, Feb. 16.

REFLECTORS.

D. W. EDGECOMB.

FOR POPULAR ASTRONOMY.

I am inclined to think that when the February number of POPULAR ASTRONOMY reaches England, there will be more or less comment among our friends there who use and admire the reflecting telescope, upon Mr. Lowell's reflections upon that instrument.

I do not know that there are many as yet in this country who feel inclined to vindicate the character or uphold the value of silver in this form, just now so much discussed otherwise. Not so many as I wish, nor so many as I hope there may be at no very distant period. The metal ought to be, I believe, much more current among observers.

I do not know how much experience Mr. Lowell has had with the silvered-glass reflector, but fear he has not given it that patient trial which he so justly recommends to all who would see, with refractors, the Martial canals and oases aright. We owe Mr. Lowell much; he sees so well, describes so graphically and reasons so justly, that next to going to Arequipa and Flagstaff ourselves, is the pleasure of reading and hearing him. Through him I have about dismissed the last remaining doubt as to the intelligent origin of the canals. A number of figures thrown down at random would be about as likely to arrange themselves into the multiplication table, as the system of lines upon the surface of Mars to have originated otherwise than by intelligent planning; and by an intelligence that operates precisely as ours does.

I do not stand below any in my admiration for the Clark glasses and have no doubt that those by Mr. Brashear are equally worthy of it. But there are enough to speak for refractors, let them look to it; I stand for reflectors. As the controversy has not as yet occupied much space in POPULAR ASTRONOMY, perhaps a brief reference to the experience of certain observers may be admissible, as against that of Mr. Lowell.

In his Life and Works of William Herschel, Professor Holden, referring to Herschel's observations of both Enceladus and Mimas seen in contact with the ball of Saturn, says:

"I have never seen so good definition, telescopic and atmospheric, as he must have had on this occasion." p. 195.

I do not know of anything that has been said by the most earnest admirer of the reflector, that can equal this statement of its superiority, by Professor Holden. For it was written, it should be remembered, when the telescope with which the satellites of Mars were discovered had been erected some years in the Observatory where he was engaged, and after he had used other refractors by the very best of modern makers.

There is in point of fact, an easy explanation of the cause that gave rise to the statement. Herschel, as we all know, observed in the open air. He worked whole nights, and night after night, in this way by the side of his telescope. The definition to be had at certian moments under such conditions, with a perfect reflector, cannot be excelled, if, indeed, it can be equaled, under any other circumstances or by any other means.

I think I am justified in saying that the 13-inch reflector of Mr. De La Rue, by means of which the well-known drawings of Jupiter and Saturn of 1856 were made, was of a defining power that

has never been excelled. Surely Mr. Lowell for the moment forgot these when he spoke so "lamentably" of the portraits of the planets by reflectors. Have not these really stood at the head of all portraits of the planets, unless we except those of Browning and Green, on account of their perfect coloring, and which were also made with reflectors?

Mr. Dawes was a good judge of definition. It will be remembered that on a certain September night, he was visiting Mr. Lassell in his Observatory at Starfield. They had the 9-inch reflector pointed at Saturn, and Mr. Dawes wrote:

"Having obtained a fine adjustment, I presently perceived the outer ring to be divided into two. For some moments I scrutinized this interesting object, and occasionally for several seconds together had by far the finest view of Saturn that I was ever favored with." Smyth's Cycle, Vol. I, p. 195.

The observer who probably came nearest to the discovery of the canals, before Schiaparelli, was Mr. Green at Madiera, with the 13-inch silvered mirror; and his portrait of the planet is the nearest correct, if that of Schiaparelli is correct, as Mr. Lowell is, evidently, ready to testify. Mr. Green's pictures of the recession of the south polar snow, and the detached patches left behind in sheltered places, are near to the drawings of Mr. Lowell and Mr. Pickering. Might it not be said that Mr. Green really had the discovery of the canals in his grasp there at Madeira? And how near the reflector came to being most uncommonly denounced for it, to be afterwards, of course, vindicated and praised! But the grasp was not quite strong enough, and while hesitating to claim these remarkable features until he had further confirmations they revealed themselves to the persevering and keen sighted Italian.

Mr. Stanley Williams, of Brighton, England, stands high as an observer. So far as I have been able to learn, he has seen more upon Mars, with his 6½-inch reflector, and more correctly—if Mr. Lowell has seen correctly (he will pardon the "if," it serves so well to give point to my statement)—than any refractor has shown in that country. And if I remember aright, Mr. Pickering found in Mr. Williams' observations perhaps the best confirmation of what he saw with the 13-inch Clark at Arequipa, upon the floor of Plato, and some other portions of the Moon.

I used for some years a refractor of 9.4-in. aperture, as good, perhaps, as any that has been made. I used also for quite a long time a 12-inch reflector, and I have used those of other sizes. I have said, and again say that I have had better definition of the

Moon and planets with the reflector than with the refractor. It was a better and more powerful instrument in nearly every way. And from my experience I believe that Mr. Brashear or my brother can make reflectors, of equal diameters to the glasses at Flagstaff, that would show, under conditions equally favorable to them, as sharply, as distinctly, every object which Mr. Lowell has seen upon Mars from that station.

And now, how shall we take the last sentence in this rather remarkable paragraph in Mr. Lowell's article? Non venenum in cauda. Surely he "nods" a little here:

"In those rare instances where much has been seen by a reflector it has been seen by the observer *in spite of his instrument, not in consequence of it*!"

And Herr Brenner whose eye, and telescope and location we admire and almost envy, he too nods just a little.

In the English Mechanic of Jan. 18th speaking of the straightness of Jupiter's belts as he sees them, he says: "An English astronomer asked me whether I really saw the bands *as straight* as I drew them, remarking that he does not. This query astonished me, for the grey bands are certainly as straight as if drawn with a ruler. * * * I suppose therefore, that the specula generally used in England *show often straight lines sinuous*." He deftly gets to cover, however, by adding in parenthesis, "This is only a supposition. I may perhaps be wrong."

Mr. Lowell's expression, however, has given me a word for which I may well say, "I thank thee." All refractors which I have ever looked through showed color. I presume that those which Mr. Lowell has used do so. All the light is not gathered into the image, but some appears as a diffused halo about it. Now is it not the strictest expression of a scientific truth to say: that the details shown to Mr. Lowell by the refractor, say upon Mars, have been seen by him "in spite of" the *imperfection* of his instrument?

And that reminds me that in the advertisement by Messrs. Cooke & Sons of their new triple object-glass, they claim that it has the merit of being as free from color as a reflector; and they quote from Dr. Roberts' report upon the performance of one of these glasses, that he found upon trial, that "the diffraction rings were faint and narrow and with excellent definition. The appearance of the objects was similar to those when viewed in a good reflector;" while as a photo-instrument he found it about equal in efficiency to an equal area of his large silvered-glass reflector. When I showed this to Mr. Clark the other day he was

much amused, "that they should claim their object-glasses to be as good as a reflector." But to those who highly value the reflector it signifies much.

As I have said, I yield to none in my admiration of the Clark glasses; and it may interest the reader to learn of what has appeared to me a fine piece of work just accomplished at his establishment.

I have long been interested in binocular telescopes, and have put many together with objectives from 2¼-inch upwards.

When in England I had Sir Howard Grubb make for me one of his binoculars with prismatic eyepieces, and object-glasses five inches in diameter. I have been so pleased with the somewhat remarkable performance of this instrument, that I wished to extend the application of the principle as far as the conditions would permit; and I asked Mr. Clark to make for me two object-glasses of 6¼-inches aperture. When I asked him how near to the same focus he could work them, he said without hesitation within a hundredth of an inch. I thought to myself there would be a good deal of work in that.

Having selected the best material, the two lenses of each sort being cut from the same piece, I soon saw, as the work on the two progressed that Mr. Lundine, his most admirable assistant, was fully equal to what Mr. Clark had said. They are now pronounced as perfect as possible, and, what seems to me remarkable, it is quite impossible to detect the slightest difference between them. They were worked to this perfect similarity by Mr. Lundine, under the supervision, of course, of Mr. Clark, without apparent difficulty, or so far as I could see, any extra labor; and without any different adjustment of one from the other by different separation of lenses or otherwise, to bring their foci together. The cells are made precisely alike. The focal length is about 94 inches. We have all tried them by setting the focus as carefully as we could upon a star, with a high power, say 500, with one of the objectives, and then substituting the other, without touching the adjustment of the eyepiece. We are unable to detect any difference in the image in color or otherwise. The difference in focal length is within the limit of our most careful adjustment with the above power. It is certain that it does not exceed one-hundredth of an inch. The five inch object-glasses of Sir Howard Grubb differ in focal-length about one-tenth of an inch.

The prisms for the instruments have been cut from the best glass procurable, and, if agreeable to the editor I shall be pleased to give some account of the 6¼-inch binocular when finished and mounted.

THE CLIMATE OF MARS.

MARSDEN MANSON.

The fact that Mars presents phenomena which indicate milder polar climates than exist upon the Earth seems to puzzle many students of astronomy. Instead of endeavoring to account for these phenomena by logical deductions from admitted facts and known laws, some seem to find pleasure in exercising their ingenuity by ascribing remotely possible conditions, and then in accounting for these conditions by processes of argument which strain the faith of their co-workers beyond its limit of elasticity.

The writer will endeavor to show that the climatic conditions, generally admitted to exist upon Mars, can be explained without resorting to suppositions and hypotheses bordering near the limits of common sense. The arguments will be simple and fundamental. Until these simple explanations shall be shown to rest upon incorrect premises, or that wrong conclusions have been drawn, the scientific imagination should be restrained within reasonable bounds.

The mean distance of Mars from the Sun is about one and one-half times the mean distance of the Earth; and its volume is about one-seventh that of the Earth. Unlike the rest of the planets, its own and other satellites, Mars reflects a rich ruddy light—an important factor in interpreting climatic conditions. Upon equal areas the heat and light received by Mars is less than one-half that received by the Earth; it by no means follows that its climates are proportionately colder, for the actual amount of heat a planet receives is not the only prime factor in its surface temperatures. There are other factors which bear an important part, and arguments omitting these are fallacious. It is the omission of these factors which has rendered the climatic conditions prevalent upon Mars difficult of interpretation, and has caused some astronomers to doubt the prevalence of milder climates upon Mars than upon the Earth. Others have considered the propriety of substituting some other substance than water to account for the formation and disappearance of the polar snow-caps*.

As either pole of Mars emerges from its winter, comparatively white spots are observed to encircle it. These spots generally reach down to Lat. 84° or 82°, or 6° or 8° from the pole, although the snow sometimes extends down to latitude 60° to 55°, or

* *Publications* A. S. P., Vol. VI, No. 38, p. 300.

through an arc of from 60° to 70°; they disappear in whole or in part as the pole is towards the Sun in the following summer. The diappearance on the edges is rapid, but the true polar spots are persistent for months. These phenomena admit of the simple explanation usually rendered, namely, that these spots are polar snow-caps which form and melt off with the seasons; but the task of explaining how a planet receiving less than half the heat and light which the Earth receives could enjoy so mild a winter and so warm a summer at polar latitudes has been hitherto considered difficult.

Dr. Bates* argues that these polar spots may be fields of carbon di-oxide (CO_2), and his theory is accredited with having much in favor of it by Professor Campbell† of the Lick Astronomical Department of the University of California. Neither authority accounts for what would have become of any water which may have existed upon Mars, and which would have been condensed before the carbon di-oxide; nor why upon the evaporation of the carbon di-oxide, we do not see the equally white snow and ice which must have been frozen and precipitated before the planet reached the extremely low temperature at which carbon di-oxide congeals. Before this remarkable interpretation can be discussed, it must be shown that water never did exist upon Mars, for it would have been congealed first, and would have shrouded the planet in white, upon which surface the condensation and evaporation of the equally white carbon di-oxide could not be observed. The same is true for any other substitute having a freezing point between that of water and — 109° Fahr.—the freezing point of carbon di-oxide. Whatever may be the freezing point of the substance causing the polar snow-caps, this substance has the highest, not the lowest freezing point of the congealable constituents of the atmosphere of Mars, for upon its evaporation we observe the general surface of the planet.

The Omitted Factors.

In the life of a planet there is a period between the final exhaustion of its own available heat, and the reign of solar heat, during which period glacial conditions are extensive and permanent for a great length of time. This period the Earth has manifestly passed through, as continental glaciers once existing have disappeared, and their feeble remnants are yet retreating upwards and polewards in tropical, temperate and even polar latitudes. This retreat is very slow, but is distinctly noticeable wherever gla-

* *Publications* A. S. P., Vol. VI., pages 300-302.
† *Ib.*, page 280.

ciers yet rest. It therefore follows that since the period when these glaciers were more extensive, there has been a general rise in temperature. As this rise is yet in progress, it must be accounted for by laws now active.

It has been previously stated that the actual amount of heat received by a planet was not the sole factor influencing its surface temperatures; other factors are equally and probably more important. Their existence and influence are made apparent in the general rise in terrestial temperatures since the culmination of the period of great glacial extension over now temperate and tropical areas. One of these factors or causes is the power of the atmosphere to trap heat. Tyndall* and Buff† have shown that by contact with the planetary surface solar light and heat-rays are converted into dark heat-rays, and are trapped; and that this power to trap dark heat-rays is held individually and collectively by the various constituents of the atmosphere. Some gases, and notably the odor of flowers, possess this power to high degree. Now, when this heat-trapping process is inaugurated upon a planet, it is no longer a heat-losing body, but a heat-gathering body in space; for its rate of receipt of heat is greater than its rate of loss. The process has a moderate limit fixed by the evaporation of water, which evaporation, when excessive, shuts out solar energy by extensive cloud formation.‡ The mean surface temperatures of the Earth have thus gradually risen from the lower temperatures prevailing during the past glacial extension. As the progress of this rise is yet being recorded by the retreat of glaciers in both hemispheres and at all latitudes, and as it was inaugurated at a comparatively remote period in the past, the factor time has entered into the result as a third important cause. Thus the solar climates of a planet are determined by three prime causes, or factors: first, the actual amount of heat or light received; second, the heat-trapping power of its atmosphere—determining the difference between its rate of receipt and rate of loss of heat; third, the time these two factors or causes have been operating.

In the application of this reasoning to Mars, we can fix, in general terms, the comparative value of each cause; the logical result of the combination being that Mars must enjoy a milder climate than the Earth.

* *Proceedings Royal Society*, Vol. XIII, page 160; *Archives des Sciences*, Berne, Vol. V, page 293.

† *Ib.*, Vol. LVII, page 293.

‡ The climate of Venus seems to be thus modified.

As regards the first, the amount of heat and light Mars receives is readily calculated to be about 0.43 that received by the Earth.

The existence and operation of the second cause is made manifest by the deficiency of blue rays and the excess of red and orange rays in the solar light Mars transmits to us, thus establishing the fact that the Martian atmosphere has the power of abstracting and retaining those rays which are most readily trapped by the atmosphere of the Earth. This deficiency in the rays most readily trapped shows that there is a positive difference between the rates of receipt and loss of solar energy; or in other words that, Mars, like the Earth, is either a heat-gathering body, and that its surface temperatures are yet gradually rising; or, that its surface temperatures are constant, and the excess of solar energy is used in maintaining these constant conditions, and in work upon the planet's surface.

The third cause—the factor time—is necessarily greater than the corresponding factor in the case of the Earth; for Mars, having a mass less than one-ninth that of the Earth, lost his internal heat at an earlier period, and therefore became a heat-gathering body at an earlier period than the Earth.

Thus all three of the prime causes are positive in their effects, irrespective of a constant or slowly decreasing source of heat, and omitting the unknown, but positive and constant factor—stellar heat. It is therefore reasonable to conclude that the phenomena observed are correctly interpreted to mean that Mars enjoys a milder general climate than the earth.*

This reasoning admits of application to any planet of any system, and it is reasonable to infer that similar climatic conditions must in time be established upon any planet having a heat-trapping atmosphere.—*No. 39, Publications of the A. S. P.*

San Francisco, Cal., January 27, 1895.

PLANET NOTES FOR MAY.

H. C. WILSON.

We present this month a sort of diagramatic orrery, which will show at a glance the approximate relative positions of the planets. In each case the length of the arrow represents the amount of the planets motion during the month. The distances of the outer planets Jupiter ♃, Saturn ♄, Uranus ♅ and Neptune ♆, are not represented to scale, since their orbits are too enormous as compared with that of the Earth ⊕. Those of Mars ♂, Venus ♀ and Mercury ☿, are on

* The supposed Martian Arctic explorer, referred to by Professor Campbell, has a trip corresponding to a summer jaunt through Norway and Sweden. Probably an equally pleasant trip awaits future explorers of our polar regions.

about the same scale with that of Earth. The signs of the zodiac and the constellations in which the planets will appear are shown by the circles around the diagram. We have inserted only the stars of the first and second magnitudes which lie in or near the zodiac.

It will be noticed at once that the limits of the signs of the zodiac do not now coincide with those of the constellations of the same name. This is because of the precession of the equinoxes, which in the last two thousand years has caused the first point of the Sign Aries, ♈, to move westward among the stars nearly 30°, so that is now near the western limit of the constellation Pisces. The sign Taurus ♉ coincides nearly with the constellation Aries, Gemini II with Taurus, Cancer ♋ with Gemini, etc.

As seen from the Earth ⊕ the Sun, during the first 20 days of May, will be in the sign Taurus but in the constellation Aries.

♈ = Aries.	♌ = Leo.	♐ = Sagittarius.
♉ = Taurus.	♍ = Virgo.	♑ = Capricornus.
♊ = Gemini.	♎ = Libra.	♒ = Aquarius.
♋ = Cancer.	♏ = Scorpio.	♓ = Pisces.

Mercury will begin the month behind the Sun. On the 4th at 6 P. M. central time he will be at superior conjunction. Twelve hours later the planet will pass the ascending node of his orbit, crossing the ecliptic from south to north. On the 9th at 8 P. M. he will be at perihelion; on the 19th at 6 P. M. will pass by Neptune;

and on the 25th at $9^h\ 44^m$ P. M. will be in conjunction with the Moon, 2° 44′ south of the latter. On the last days of the month Mercury will be visible as evening star for a short time after sunset, between the stars γ Geminorum and β Tauri.

Venus, Jupiter and *Mars* will be in the same part of the heavens. The latter has diminished so much in brightness that he is now only equal to an average first magnitude star, almost exactly like, in color and brightness, to Aldebaran or Betelgeux. The two former are very brilliant and alike in color. In May Venus will somewhat surpass Jupiter in brilliancy. The two will be in conjunction May 18 at 10 A. M. Venus will then be 2° 5′ or about four diameters of the Moon north of Jupiter. The Moon will pass Jupiter May 26 at $6^h\ 42^m$ P. M., Venus May 27 at 9 A. M. and Mars May 27 at 5 P. M. If conjunctions of the planets have anything to do with the weather we may look out for stormy times in these months.

Saturn and *Uranus* will be in a different quarter of the heavens, being seen toward the southeast in the evening, in the constellations Virgo and Libra. Saturn and Spica (α Virginis) are almost equal in brightness and not very different in color, Saturn being of a duller, more golden, hue than the star. Arcturus (α Boötis) is north of Saturn and is of an orange red color. The Moon will pass Saturn May 7 at $7^h\ 35^m$ P. M. and Uranus May 8 at $8^h\ 4^m$ P. M. The latter will be at opposition at noon May 8.

Neptune though in the same region of sky with Venus and Mercury cannot be seen on account of its faintness.

Planet Tables for May.

[The times given are local time for Northfield. To obtain Standard Times for places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
May 5.....	2 53.3	+ 16 37	4 48 A. M.	12 0.0 P. M.	7 12 P. M.
15.....	4 19.7	+ 23 57	5 5 "	12 47.0 "	8 29 "
25.....	5 37.3	+ 25 36	5 28 "	1 25.2 "	9 22 "

VENUS.

May 5.....	5 21.9	+ 24 57	6 26 A. M.	2 28.5 P. M.	10 20 P. M.
15.....	6 13.4	+ 25 31	6 45 "	2 40.7 "	10 36 "
25.....	7 4.2	+ 24 55	7 00 "	2 52.1 "	10 44 "

MARS.

May 5.....	6 35.9	+ 24 40	7 51 A. M.	3 42.3 P. M.	11 33 P. M.
15.....	7 2.3	+ 24 7	7 41 "	3 29.3 "	11 17 "
25.....	7 28.6	+ 23 18	7 32 "	3 16.2 "	12 00 "

JUPITER.

May 5.....	6 17.7	+ 23 27	7 39 A. M.	3 23.9 P. M.	11 69 P. M.
15.....	6 25.9	+ 23 24	7 8 "	2 52.8 "	10 38 "
25.....	6 34.7	+ 23 19	6 38 "	2 22.3 "	10 6 "

SATURN.

May 5.....14	7.2	− 10 0	5 50 P. M.	11 11.9 P. M.	4 33 A. M.
15.....14	4.5	− 9 46	5 6 "	10 29.9 "	3 54 "
25.....14	2.1	− 9 36	4 23 "	9 48.1 "	3 13 "

URANUS.

May 5.....15	2.7	− 16 52	7 19 P. M.	12 13.4 A. M.	5 7 A. M.
15.....15	0.9	− 16 45	6 43 "	11 37.6 P. M.	4 33 "
25.....14	59.3	− 16 39	5 53 "	10 48.4 "	3 43 "

NEPTUNE.

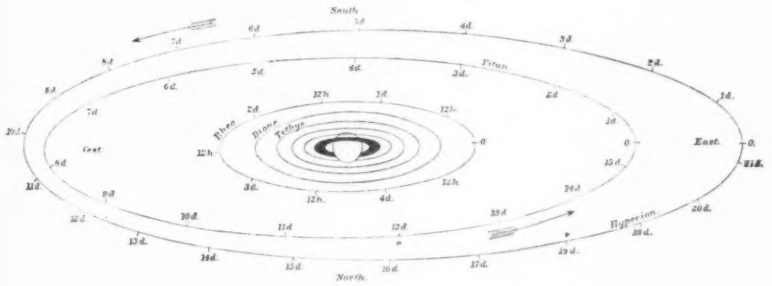
May	5.....	4	52.8	+21	8	6	30	A. M.	2	3.3	P. M.	9	36	P. M.
	15.....	4	54.3	+21	10	5	48	"	1	21.2	"	8	54	"
	25.....	4	55.8	+21	13	5	10	"	12	43.5	"	8	16	"

THE SUN.

May	5.....	2	49.9	+16	20	4	45	A. M.	11	56.5	A. M.	7	8	P. M.
	15.....	3	28.9	+18	56	4	33	"	11	56.1	"	7	19	"
	25.....	4	8.9	+21	00	4	23	"	11	56.7	"	7	33	"

Saturn's Satellites.

[E = east elongation; I = inferior conjunction (south of planet); W = west elongation; S = superior conjunction (north of planet). In the diagram the points of the orbits marked O are those of eastern elongation, as seen in an inverting telescope. The Central Standard times when the satellites will be at these points are given in the tables that follow. The points on the orbits marked 1*d*, 2*d*, etc., indicate the places of the satellites at the intervals 1 day, 2 days, etc., after the time given for eastern elongation.]



I MIMAS. PERIOD 0*d* 22^h.6.

		h			h			h	
May	1	4.7	A. M. E	May 12	11.4	P. M. W	May 23	7.4	P. M. E
	2	3.3	" E	13	10.0	" W	26	3.9	A. M. W
	3	1.9	" E	14	8.6	" W	27	2.5	" W
	4	12.5	" E	15	7.2	" W	28	1.2	" W
	4	11.1	P. M. E	18	3 8	A. M. E	28	11.8	P. M. W
	5	9.8	" E	19	2 4	" E	29	10.4	" W
	6	8.3	" E	20	1.0	" E	30	9.0	" W
	7	6.9	" E	20	11 6	P. M. E	31	7.7	" W
	10	3.5	A. M. W	21	10.2	" E			
	11	2.1	" W	22	8.8	" E			
	12	12.7	" W						

II ENCELADUS. PERIOD 1*d* 8^h.9.

May	2	4.2	A. M. E	May 13	3.2	A. M. E	May 24	2.2	A. M. E
	3	1.1	P. M. E	14	12.1	P. M. E	25	11.1	" E
	4	9.9	" E	15	8.9	" E	26	8.0	P. M. E
	6	6.8	A. M. E	17	5.8	A. M. E	28	4.9	A. M. E
	7	3.7	P. M. E	18	2.7	P. M. E	29	1.8	P. M. E
	9	12.6	A. M. E	19	11 6	" E	30	10.7	" E
	10	9.5	" E	21	8.5	A. M. E			
	11	6.3	P. M. E	22	5.4	P. M. E			

III Tethys. Period 1*d* 21^h.3.

May	1	7.2 A. M. E	May	12	2.9 P. M. E	May	23	10.7 P. M. E
	3	4.5 " E		14	12.2 " E		25	8.0 " E
	5	1.8 " E		16	9.5 A. M. E		27	5.3 " E
	6	11.1 P. M. E		18	6.8 " E		29	2.6 " E
	8	8.4 " E		20	4.1 " E		31	11.9 A. M. E
	10	5.7 " E		22	1.4 " E			

IV Dione. Period 2*d* 17^h.7.

May	2	12.6 A. M. E	May	12	11.2 P. M. E	May	23	9.9 P. M. E
	4	6.3 P. M. E		15	4.9 " E		26	3.5 " E
	7	11.9 A. M. E		18	10.6 A. M. E		29	9.2 A. M. E
	10	5.6 " E		21	4.2 " E			

V Rhea. Period 4*d* 12^h.4.

May	1	4.4 A. M. E	May	14	5.4 P. M. E	May	23	6.0 P. M. E
	5	4.7 P. M. E		19	5.7 A. M. E		28	6.4 A. M. E
	10	5.1 A. M. E						

VI Titan. Period 15*d* 3^h.3.

May	1	9.9 A. M. E	May	13	12.0 M. S	May	25	8.6 A. M. W
	5	6.8 " I		17	7.6 A. M. E		29	9.5 " S
	9	11.0 " W		21	4.5 " I			

VII Hyperion. Period 21*d* 7^h.8

May	1	2.0 A. M. W	May	11	8.5 A. M. E	May	22	7.2 A. M. W
	5	2.0 P. M. S		17	11.8 " I		26	7.2 P. M. S

VIII Japetus. Period 79*d* 22^h.0.

Apr.	23	8.9 A. M. S	May 13	7.3 A. M. E	May 31	4.7 A. M I.

Phases and Aspects of the Moon.

		Central Time. d	h	m	
First Quarter	May	1	9	44	P. M.
Perigee		4	3	50	A. M.
Full Moon		8	5	59	P. M.
Last Quarter		16	11	44	A. M.
Apogee		16	1	50	P. M.
New Moon		24	6	46	A. M.
Perigee		29	4	30	"
First Quarter		31	2	48	"

Occultations Visible at Washington.

Date 1895		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	IMMERSION. Angle f'm N p't. °	EMERSION. Washington M. T. h m	EMERSION. Angle f'm N p't. °	Duration. h m
May	6	*i* Virginis	5.7	11 47	59	12 19	6	0 31
	7	B.A.C. 4722	5.8	8 44	151	9 50	260	1 6
	9	B.A.C. 5347	6.0	8 20	83	9 16	325	0 56

Jupiter's Satellites for May.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I. d r

III. d r

II. d r

IV. d r

Configurations at 7h 30m for an Inverting Telescope.

Day.	West.	East.
1	·1 ·3 ○ ·2	4·
2	○ 1· 2· ·3	4·
3	2· ·1 ○	3· 4·
4	·2 ○ ·1 3· 4·	
5	○4· 3· ·1 ○ ·2	
6	○1· 3· ·4 ○ 2·	
7	4· ·3 2· ○ ·1	
8	4· 1· ·3 ○	·2●
9	4· ○ ·1 3· 2·	
10	·4 ·12· ○	3·
11	·4 ·2 ○ 1· 3·	
12	○3· ·4 1· ○ ·2	
13	·3 ·4 ○1· 2·	
14	·3 ·2 ○ ·4	·1●
15	·3 ·1 ○ ·4	·2●
16	○ 1· ·3 2· ·4	
17	1· 2· ○ ·3 ·4	
18	·2 ○ 1· ·3 4·	
19	·1 ○3· 2· 4·	
20	3· ○ 1· 2· 4·	
21	·3 ·2 ○ ·4	1●
22	·3 4· 1· ·2 ○	
23	4· ○ ·1 ·3 ·2	
24	○2 ·4 ·1 ○ ·3	
25	·4 ·2 ○ ·1 3·	
26	4· ·1 ○ 3· ·2	
27	·4 3· ○ 1· 2·	
28	·4 3· 2· ·1○	
29	○1· ·4 ·3 ·2 ○	
30	4· ○ ·1 ·2	·3●
31	1· ○2· ·4 ·3	

Phenomena of Jupiter's Satellites.

Central Time.

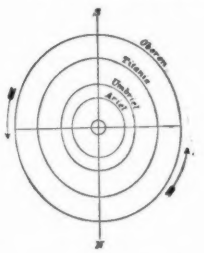
May	1	10	16	A. M.	I	Sh. In.	May	10	9	3	A. M.	I	Sh. Eg.
		11	18	"	I	Tr. Eg.			10	00	"	II	Tr. In.
		12	33	P. M.	I	Sh. Eg.			12	5	P. M.	II	Sh. In.
		1	36	"	II	Oc. Dis.			1	55	"	II	Tr. Eg.
		2	14	"	II	*Ec. Re.			2	47	"	II	Sh. Eg.
		6	57	"	III	Oc. Dis.			4	40	"	I	Oc. Dis.
		10	54	"	III	Oc. Re.		11	4	06	A. M.	I	Ec. Re.
	2	1	58	A. M.	III	Ec. Dis.			7	17	"	I	Tr. In.
		3	7	"	III	Ec. Re.		12	1	16	"	I	Sh. In.
		6	9	"	I	Oc. Dis.			2	10	"	I	Tr. Eg.
		7	36	"	I	Ec. Re.			3	33	"	I	Sh. Eg.
		10	53	"	I	Tr. In.			4	28	"	II	Oc. Dis.
	3	4	46	"	I	Sh. In.			6	22	"	II	Ec. Re.
		5	47	"	I	Tr. Eg.			10	51	"	III	Tr. In.
		7	2	"	I	Sh. Eg.			5	29	P. M.	III	*Tr. Eg.
		8	5	"	II	Tr. In.			8	35	"	III	Sh. In.
		9	18	"	II	Sh. In.			9	6	"	I	Oc. Dis.
		11	18	"	II	Tr. Eg.			10	36	"	III	Sh. Eg.
		12	00	M.	II	Sh. Eg.		13	12	18	A. M.	I	Ec. Re.
		2	3	P. M.	I	Oc. Dis.			1	46	"	I	*Tr. In.
	4	2	6	A. M.	I	Ec. Re.			7	46	P. M.	I	*Sh. In.
		5	22	"	I	Tr. In.			8	39	"	I	Tr. Eg.
		11	16	"	I	Sh. In.			10	3	"	I	Sh. Eg.
	5	12	16	"	I	Tr. Eg.			10	57	"	II	Tr. In.
		1	33	"	I	Sh. Eg.		14	1	29	A. M.	II	Sh. In.
		2	33	"	II	Oc. Dis.			3	14	"	II	Tr. Eg.
		3	36	"	II	Ec. Re.			4	11	"	IV	Oc. Dis.
		8	16	"	III	Tr. In.			5	11	"	II	Sh. Eg.
		1	8	P. M.	III	Tr. Eg.			5	59	"	IV	Oc. Re.
		4	12	"	III	Sh. In.			7	39	"	IV	Ec. Dis.
		5	6	"	IV	*Tr. In.			1	32	P. M.	IV	Ec. Re.
		7	11	"	III	*Sh. Eg.			4	21	"	I	Oc. Dis.
		8	17	"	I	*Oc. Dis.			5	6	"	I	*Ec. Re.
		8	36	"	IV	Tr. Eg.			8	15	"	I	Tr. In.
		9	34	"	I	Ec. Re.		15	2	16	"	I	Sh. In.
		10	50	"	IV	Sh. In.			4	8	"	I	Tr Eg.
	6	4	27	A. M.	IV	Sh. Eg.			4	34	"	I	Sh. Eg.
		7	16	"	I	Tr. In.			5	26	"	II	*Oc. Dis.
		5	45	P. M.	I	*Sh. In.			7	45	"	II	Ec. Re.
		6	44	"	I	*Tr. Eg.		16	12	9	A. M.	III	Oc. Dis.
		8	3	"	I	*Sh. Eg.			7	37	"	III	Oc. Re.
		9	2	"	II	Tr. In.			10	44	"	III	Ec. Dis.
		10	41	"	II	Sh. In.			11	7	"	I	Oc. Dis.
	7	12	37	A. M.	II	Tr. Eg.			11	36	"	III	Ec. Re.
		1	23	"	II	Sh. Eg.			2	12	P. M.	I	Ec. Re.
		3	21	"	I	Oc. Dis.			2	43	"	I	Tr. In.
		3	6	P. M.	I	Ec. Re.		17	8	46	A. M.	I	Sh. In.
		6	19	"	I	Tr. In.			9	37	"	I	Tr. Eg.
	8	12	15	"	I	Sh. In.			11	4	"	I	Sh. Eg.
		1	13	"	I	Tr. Eg.			11	55	"	II	Tr. In.
		2	33	"	I	Sh. Eg.			2	53	P. M.	II	Sh. In.
		3	31	"	II	Oc. Dis.			4	32	"	II	Tr. Eg.
		4	59	"	II	Ec. Re.			5	36	"	II	*Sh. Eg.
		9	33	"	III	Oc. Dis.			7	17	"	I	Oc. Dis.
	9	3	15	A. M.	III	Oc. Re.		18	6	7	A. M.	I	Ec. Re.
		6	20	"	III	Ec. Dis.			9	12	"	I	Tr. In.
		7	7	"	I	Oc. Dis.		19	3	26	"	I	Sh. In.
		9	36	"	III	Ec. Re.			4	5	"	I	Tr. Eg.
		10	11	"	I	Ec. Re.			5	34	"	I	Sh. Eg.
		12	48	P. M.	I	Tr. In.			6	23	"	II	Oc. Dis.
	10	6	46	A. M.	I	Sh. In.			9	8	"	II	Ec. Re.
		7	42	"	I	Tr. Eg.			1	27	P. M.	III	Tr. In.

May 19	9 52 P. M.	I	Oc.	Dis.
20	12 37 A. M.	III	Tr.	Eg.
	12 59 "	III	Sh.	In.
	1 6 "	I	Ec.	Re.
	3 41 "	III	Sh.	Eg.
	4 19 "	I	Tr.	In.
	9 46 P. M.	I	Sh.	In.
	10 34 "	I	Tr.	Eg.
21	12 4 A. M.	I	Sh.	Eg.
	12 52 "	II	Tr.	In.
	4 17 "	II	Sh.	In.
	5 51 "	II	Tr.	Eg.
	7 00 "	II	Sh.	Eg.
	8 36 "	I	*Oc.	Dis.
	7 7 P. M.	I	Ec.	Re.
	10 10 "	IV	Tr.	In.
22	3 17 "	I	Tr.	In.
	4 17 "	I	Sh.	In.
	5 3 "	IV	Tr.	Eg.
	5 50 "	I	Tr.	Eg.
	6 34 "	I	*Sh.	Eg.
	7 21 "	IV	Sh.	In.
	10 17 "	II	Oc.	Dis.
	10 32 "	IV	Sh.	Eg.
23	1 27 A. M.	II	Ec.	Re.
	2 45 "	III	Oc.	Dis.
	12 1 P. M.	I	Oc.	Dis.
	1 37 "	I	Ec.	Re.
	4 38 "	III	Ec.	Re.
	6 12 "	I	Tr.	In.
24	10 47 A. M.	I	Sh.	In.
	11 32 "	I	Tr.	Eg.
	1 4 P. M.	I	Sh.	Eg.
	1 50 "	II	Tr.	In.
	5 42 "	II	*Sh.	In.
	7 9 "	II	*Tr.	Eg.
	8 25 "	II	Sh.	Eg.
	9 55 "	I	Oc.	Dis.
25	8 8 A. M.	I	Ec.	Re.
	11 7 "	I	Tr.	In.
26	5 17 "	I	Sh.	In.
	6 00 "	I	Tr.	Eg.
May 26	7 35 A. M.	I	Sh.	Eg.
	8 18 "	II	Oc.	Dis.
	11 55 "	II	Ec.	Re.
	4 3 "	III	Tr.	In.
27	2 16 "	I	Oc.	Dis.
	2 38 "	III	Sh.	In.
	5 6 "	III	Tr.	Eg.
	5 24 "	I	Ec.	Re.
	5 36 "	III	Sh.	Eg.
	8 20 "	I	Tr.	In.
	11 47 P. M.	I	Sh.	In.
28	12 29 A. M.	I	Tr.	Eg.
	2 5 "	I	Sh.	Eg.
	2 47 "	II	Tr.	In.
	7 6 "	II	Sh.	In.
	8 28 "	II	Tr.	Eg.
	9 50 "	II	Sh.	Eg.
	11 13 "	I	Oc.	Dis.
	9 8 P. M.	I	Ec.	Re.
29	12 5 A. M.	I	Tr.	In.
	6 17 P. M.	I	*Sh.	In.
	6 58 "	I	Tr.	Eg.
	8 35 "	I	Sh.	Eg.
	9 16 "	II	Oc.	Dis.
30	1 19 A. M.	II	Ec.	Re.
	5 21 "	I	Oc.	Dis.
	3 39 P. M.	III	Oc.	Dis.
	4 25 "	I	Ec.	Re.
	6 33 "	III	Ec.	Re.
	10 12 "	IV	Oc.	Dis.
31	1 28 A. M.	IV	Oc.	Re.
	4 11 "	IV	Ec.	Dis.
	7 34 "	IV	Ec.	Re.
	10 34 "	I	Tr.	In.
	12 48 P. M.	I	Sh.	In.
	1 26 "	I	Tr.	Eg.
	3 6 "	I	Sh.	Eg.
	3 44 "	II	Tr.	In.
	8 31 "	II	Sh.	In.
	9 46 "	II	Tr.	Eg.
June 1	11 14 "	II	Sh.	Eg.
	12 32 A. M.	I	Oc.	Dis.

NOTE.—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse. Oc., denotes occultation; Tr., transit of the satellite; Sh. transit of the shadow; * Visible at Washington.

Satellites of Uranus.

[N = north elongation; S = south elongation]



Apparent Orbits of the Satellites of Uranus in 1895.

ARIEL. PERIOD $2^d\ 12^h.489$.

May 1	9.6 A. M.	N	May 21	1.5 P. M.	N
2	3.9 P. M.	S	22	7.8 P. M.	S
3	10.1 "	N	24	2.0 A. M.	N
5	4.4 A. M.	S	25	8.3 "	S
6	10.6 "	N	26	2.5 P. M.	N
7	4.8 P. M.	S	27	8.7 "	S
8	11.1 "	N	29	3.0 A. M.	N
10	5.3 A. M.	S	30	9.3 "	S
11	11.5 "	N	31	3.5 P. M.	N
12	5.8 P. M.	S			
13	12.0 midn.	N			
15	6.3 A. M.	S			
16	12.5 P. M.	N			
17	6.7 "	S			
19	1.0 A. M.	N			
20	7.3 "	S			

UMBRIEL. PERIOD $4^d\ 3^h.460$.

May 1	10.6 A. M.	S	May 11	7.3 P. M.	N	May 22	4.0 A. M.	S
3	12.3 P. M.	N	13	10.0 "	S	24	5.7 "	N
5	2.0 "	S	15	10.8 "	N	26	7.5 "	S
7	3.8 "	N	17	12.5 A. M.	S	28	9.2 "	N
9	5.5 "	S	20	2.3 "	N	30	11.0 "	S

TITANIA. PERIOD $8^d\ 16^h.942$.

May 3	9.9 A. M.	S	May 16	11.4 A. M.	N	May 25	4.4 A. M.	N
7	6.4 P. M.	N	20	7.9 P. M.	S	29	12.9 P. M.	S
12	2.9 A. M.	S						

OBERON. PERIOD $13^d\ 11^h.119$.

May 5	7.6 P. M.	S	May 19	6.9 A. M.	S	May 26	12.5 A. M.	N
12	1.2 "	N						

Search Ephemerides for Barnard's Comet 1884 II.

[From *Astronomische Nachrichten* No. 3260.]
For Perihelion June 3.5.

Berlin Midn.	α h	m	s	δ °	′	log r	log Δ	$1:r^2\Delta^2$
April 24	21	35	9	− 20	52.5	0.1343	0.0825	0.368
26	21	42	49	20	17.2			
28	21	50	27	19	40.7			
30	21	58	3	19	3.0			
May 2	22	5	36	18	24.1	0.1253	0.0659	0.415
4		13	6	17	44.1			
6		20	33	17	3.1			
8		27	56	16	21.2			
10		35	16	15	38.4	0.1180	0.0521	0.457
12		42	32	14	54.8			
14		49	43	14	10.5			
16	22	56	50	13	25.6			
18	23	3	54	12	40.2	0.1125	0.0409	0.493
20		10	53	11	54.3			
22		17	47	11	8.0			
24		24	36	10	21.4			
26		31	20	9	34.6	0.1091	0.0322	0.522
28		37	59	8	47.7			
30		44	33	8	0.8			
June 1		51	2	7	13.9			
3	23	57	26	6	27.1	0.1080	0.0255	0.542
5	0	3	44	5	40.5			
7		9	57	4	54.1			
9		16	5	4	8.0			
11		22	7	3	22.2	0.1091	0.0206	0.549
13		28	4	2	36.8			
15	0	33	55	1	51.9			
17		39	40	1	7.5			
19		45	20	− 0	23.7	0.1125	0.0168	0.551
21		50	54	+ 0	19.5			
23	0	56	21	1	2.1			
25	1	1	43	1	44.0			
27		6	59	2	25.2	0.1180	0.0136	0.546
29		12	9	3	5.6			
July 1		17	13	3	45.3			
3		22	11	4	24.2			
5	1	27	2	+ 5	2.4	0.1253	0.0107	0.535

At the apparition of 1884 the quantity $1:r^2\Delta^2$, which expresses the relative amount of light reflected by the comet, was as follows: July 16, 2.91; August 15, 2.97; September 14, 1.95; October 14, 0.85; November 13, 0.32; November 23, 0.24.

The uncertainty of the comet's course is shown by the following ephemerides constructed upon the supposition that the perihelion may be as much as 8 days early or 8 days late:

	Perihelion May 26.5.						Perihelion June 11.5.					
	α			δ			α			δ		
	h	m	s	°	′		h	m	s	°	′	
April 24	21	56	44	− 18	30.7		21	11	11	− 23	14.7	
28	22	11	38	17	11.3		21	26	24	22	13 3	
May 2	22	26	22	15	48.1		21	42	13	21	6.5	
1	22	40	50	14	21.6		21	57	35	19	54.1	
10	22	55	2	12	52.4		22	12	47	18	36.8	
14	23	8	57	11	21.2		22	27	47	17	15.0	
18	23	22	36	9	48.6		22	42	33	15	49.5	
22	23	35	56	8	15.3		22	57	2	14	20.9	
26	23	48	57	6	41.8		23	11	11	12	49.9	
30	0	1	38	5	8.9		23	25	0	11	17.2	
June 3	0	14	0	3	36.8		23	38	28	9	43.4	
7	0	26	1	2	6.1		23	51	34	8	9.3	
11	0	37	44	− 0	37.0		0	4	17	6	35.4	
15	0	49	6	+ 0	49.9		0	16	36	5	2.3	
19	1	0	8	2	14.4		0	28	29	3	31.1	
23	1	10	48	3	36.1		0	39	55	2	1.6	
27	1	21	8	4	55.0		0	50	56	− 0	34.4	
July 1	1	31	5	6	10.8		1	1	31	+ 0	50.1	
5	1	40	39	+ 7	23.6		1	11	38	+ 2	11.7	

PRACTICAL SUGGESTIONS.

If you do not know, ask, possibly some one can answer. Brief queries and answers are generally most useful.

92. Paragraph number 88, page 281, of these suggestions in the February number is a most important statement of the meaning of the constant *k*. It should have been credited to Professor William A. Rogers, department of Physics, Calby University, Waterville, Me. In number 87 preceding credited to the same person, the word *glass* in the fifth line should read *brass*. This was an error in copy.

93. Why do the stars appear so much nearer together at the zenith than at the horizon?

Answer: For the same reason that the Sun or Moon *appear* larger when near the horizon than in high altitude. It is plainly an illusion. If the Sun or Moon is viewed through a smoked glass when near the horizon they will appear not unusually large. If a paper tube is made just large enough to take in the diameter of the Moon while passing the meridian, the image of the Moon at the horizon will not be quite large enough to fill the circular opening of the paper telescope. Why?

GENERAL NOTES.

The publisher of this magazine very much desires to secure twenty copies of the December number of *Astronomy and Astro-Physics* for 1894. If returned soon in good condition, forty cents each will be paid for them.

We are sorry to say that a number of subscribers have not responded to our notice of dues. It is our custom to drop names from our lists if renews are not promptly made, or, at least, orders made for continuance when prepayment is inconvenient. Will all our friends please bear this in mind?

Professor C. A. Young of Princeton College has been secured for a course of three lectures, April 15, 16, 17, in St. Paul. His themes are, The Sun, The Planets, The Stars and the Nebulæ. While he is west efforts will be made to secure these lectures at other places also.

The Lunar Eclipse, March 10, 1894.—The sky was beautifully clear at Northfield and the phenomena of the eclipse were shown as clearly as we have ever seen them. Totality began about one minute later than the Almanac time. The most striking phenomenon was the gradation of light within the umbra of the shadow. At the edge of the umbra the light was quite bright so that the more prominent details of the Moon's surface could readily be seen with the naked eye. The color was a light pink. Toward the centre of the shadow the illumination lessened rapidly, becoming of a dusky copper color, in which the surface markings could scarcely be distinguished. The cross-section of this darkest part of the umbra was smaller than the disc of the Moon, and at the middle of totality was almost central on the disc. The lighter fringe around it at this time might have been mistaken for the effect of contrast with the black sky, had not its motion proved that it was real.

The Comets of the Year 1894.—These were four in number. The first was discovered by Mr. W. F. Denning at Bristol, England, March 26. It was a faint telescopic comet, but turned out to be a periodic, making its revolution in about 7.4 years. Special interest has attached to this of late from the suggestions by two computers, Drs. Hind and Lamp, that Denning's comet may be identical with the lost comet of Brorsen, which was last seen in 1879. The latest investigations by Dr. Schulhof of Paris seem to show that the two comets cannot be identical, although probably from the same source.

The second was discovered April 1 by Mr. Gale at Sidney, N. S. W., and was for a short time barely visible to the naked eye. Its orbit is apparently a parabola.

No. III was discovered May 8 by Mr. Finlay at the Cape of Good Hope, this being a return of the periodic comet bearing his name, ~~and first seen in 1886~~.

No. IV was discovered Nov. 20 by Edward Swift at Mt. Lowe Observatory, Cal. It was exceedingly faint, but turns out to be very interesting on account of its probable identity with the lost comet of DeVico, 1844 I. The following table gives the approximate elements of these comets:

No.	Perihelion	Ω	ω	i	q	e
		° ′	° ′	° ′		
I	Feb. 9.727	83 52	46 56	5 35	1.1508	0.711
II	Apr. 13.520	206 21	324 18	87 3	0.9834	
III	Apr. 23.247	121 10	185 5	12 44	1.3506	0.551
IV	Oct. 12.188	48 45	296 35	2 58	1.3920	0.572

Encke's periodic comet, *d* 1894, which was seen first by Cerulli Nov. 1, passed its perihelion Feb. 7.74, 1895, and so belongs with the comets of 1895.

The Study of Physical Astronomy.—We have rarely published, during the last fourteen years, a series of more important articles than those now being given in this magazine, by Dr. T. J. J. See of the University of Chicago, concerning the study of physical astronomy in the college and university. The foundation he lays is not too broad for the present needs in this country. He shows a bold historic background that is tremendously exhilirating; he gives cogent reasons why the energies of American youth should now be set to a new key of masterful endeavor for higher and better attainment in a most worthy and promising field of action, and he does not fail to point out with startling clearness the woful defects in judgment that prevail in shaping some courses of study, in the higher institutions of learning in this country. Letters from eminent scholars in different parts of the United States support his views most heartily, and signify plainly that broad and effective scholarship in the essentials of mathematics and astronomy will not long be wanting here with such leadership if we can have enough of it.